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ABSTRACT

This workbook is utilized in connection with a 40-hour course on sanitary surveys of water supply systems for biologists, chemists, and engineers with experience as a water supply evaluator. Practical training is provided in each of the 21 self-contained modules. Each module outlines the purpose, objectives and content for that section. The course stresses evaluation of structural and functional components of water supply systems. Structural components discussed include the physical plant, operations, maintenance, and administration. Functional components include the collection, treatment, distribution and control phases of these systems. (CS)

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CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

STUDENT WORKBOOK

This Student Workbook was developed by New England Research, Inc. under contract number 68-01-4239 with the Region V Water Supply Branch of the United States Environmental Protection Agency.

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SE 023 411

SECTION A

INTRODUCTION

The Safe Drinking Water Act (SDWA) of 1974 (P.L. 93-523) expressed the intent of the United States Congress to ensure that all Americans enjoy a supply of safe drinking water. The act mandates the development of drinking water standards and their enforcement. It also requires studies and educational programs to assist in the implementation.

Even prior to SDWA most states had programs for continuous monitoring of water supply systems. These were designed to ensure that each community had a continuous supply of potable water which met public health standards. These evaluations are also intended to assist local water supplies to identify potential sources of problems either in terms of quantity or quality. The passage of the SDWA provided added impetus to assist state evaluators in conducting thorough reviews of water supply systems.

The specific objectives of this course are as follows:

(1) to train the evaluator to perform a comprehensive evaluation of a water supply system.

(2) to train the evaluator to determine if there is sufficient information available to define any problems and their potential solutions.

(3) to train the evaluator to identify potential causes for inadequate performance such as maintenance, process control procedures, design, management, etc.

(4) to train the evaluator to analyze the available data to determine what corrective actions will be effective.

(5) to train the evaluator to provide liaison between the Federal and state jurisdictions and the local water supply system.

The course is intended to provide practical training. It is also intended to provide training in all areas of evaluation, even if these are not now covered by existing state programs.

The approach of the course is to provide general evaluation criteria in each area of consideration. Exhaustive checklists have not been supplied. This approach allows flexibility for each state to interject their own policy as they see fit.

The course assumes that the participants will have a technical degree at the bachelor's level or equivalent. It is expected that there will be a wide range of backgrounds including biologists, chemists, engineers, etc. It is expected that the student will have 0 - 3 years experience as a water supply evaluator.

The Student Workbook has been written to be used as an integral part of this course. The subject matter has been divided into 21 self-contained modules. Your instructor may select the modules he considers to be most relevant to the evaluation task in your state. Because of cross-referencing it may be necessary for you to study more than the module under consideration. To assist you in finding all of the material relevant to a particular module, you may refer to Table A.1 .

The subject matter of each module will be discussed in one or more class sessions. Your instructor has developed an appropriate schedule (See SECTION D) of sessions to cover the modules he has selected. The entire course requires 40 contact hours. Your instructor has adjusted the total time to fit the selected modules. The subject matter will not be covered necessarily in the same order as it appears in this book.

The course requires substantial classroom participation on your part. Besides general discussions, case studies, work groups, and role-playing sessions will be used. There will be several quizzes also. Films, slides, transparencies, handouts and homework are also included in the course. In some places in the text you will find room for additional notes. Section G contains additional blank notepaper to be used as needed and inserted in the appropriate section. There is also a list of additional readings which will help you get started on more in-depth study in any areas of particular interest.

MODULE	OTHER RELEVANT MODULES
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Module No. 8	7, 10, 11, 15
Module No. 9	5, 6, 10
Module No. 10	9, 11, 13
Module No. 11	10, 18, 19
Module No. 12	10, 14, 15
Module No. 13	10, 12, 15, 18
Module No. 14	12, 18
Module No. 15	8, 12, 18, 19
Module No. 16	All Modules
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Module No. 21	All Modules

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PRE-COURSE ACTIVITIES

Pre-Course Survey Forms

It will be helpful to the instructor to have each student fill out two brief forms prior to the beginning of the course. They are the Biographic Statement and Participant Survey. Please hand these in prior to the course.

Pre-Course Activities

The sanitary survey has been given increased attention under the SDWA and the Natural Interim Primary Drinking Water Regulations. The student should review both the Act and the Regulations prior to the course paying particular attention to the references to the sanitary survey. The student should also read over Modules 1 - 4. These four modules provide the basis for the technical modules which follow.

BIOGRAPHIC STATEMENT

For Training Course

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

Please Print:

NAME: ______________________________ DATE: __________

PRESENT JOB TITLE: ____________________ DATE OF BIRTH:

______________________________________ ______________

OFFICE ADDRESS: ____

____

____

EDUCATIONAL DEGREES: ___________________________________
(Include Area of Specialization)

____

JOB FUNCTION OR
RESPONSIBILITY: ____

____

____

OTHER COURSES TAKEN
RELATIVE TO JOB: _______________________________________

____

PARTICIPANT SURVEY

For Training Course

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

(1) Please identify 5 - 10 job skills in which you think you are fully competent (i.e., things you have to know or be able to do in order to do your job).

(2) List 5 - 10 job-related skills you would like to know more about.

(3) List the three most important things you would like this course to do for you.

NAME: ______________________________

SECTION D

COURSE SCHEDULE

SECTION E

COURSE MODULES

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 1

ORIENTATION

TITLE OF COURSE:
CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:
ORIENTATION

PURPOSE:
The purpose of this module is to identify the objectives of the total course, and to familiarize each student with course materials, instructors and other students.

OBJECTIVES:
(1) The student will be able to identify the objectives of the total course, and will be able to relate those objectives to his task as an evaluator.
(2) The student will be able to explain the organization of the workbook, and how it relates to classroom and field activities.

CONTENT:

Introduction
Course Objectives
Student Workbook and Course Structure

OTHER RELEVANT MODULES:

All Modules

Introduction

This is a practical training course on the evaluation of water supply systems. Some of you have already had experience in evaluating different types of water supply systems; others have not. This course is therefore designed to build upon experience you have had, and to guide your future evaluation experience. The evaluation of water supply systems, after all, is a complex task involving highly technical, observational and social and communicative skills. Its complexity requires our constant attention to changes in technology, changes in knowledge, and changes in legislative and administrative guidelines that affect the evaluation process. In the past several years alone, Congress has enacted the Safe Drinking Water Act (P.L. 93-523) which amends the Public Health Service Act with a comprehensive program for ensuring the safety of public water supply systems. Included in this act are provisions for interim primary regulations which, after a period of study of health effects of contaminants, will be revised. The provision for such revisions reflects congressional recognition that the interpretation of water quality parameters and our understanding of the role they may play in public health are dynamic issues. State action in the area of water supply systems is also an important aspect of the Safe Drinking Water Act, and will serve to give direction and emphasis to the role of evaluation in maintaining high public health standards for water supply systems.

Course Objectives

The purpose of this course is to identify and upgrade our understanding of major elements in a comprehensive evaluation of water supply systems. Such an evaluation should include consideration of various structural and functional components of water supply systems. Structural components which will be considered include the physical plant and equipment, operations, maintenance and administration. Functional components include the collection, treatment, distribution and control phases of these systems. In addition, a comprehensive evaluation must include an evaluation of sources of information, including recorded data, specifications, published guidelines, and information received from plant and other personnel (Figure 1.1) . Upon completion of this course, the student will therefore be provided with information to perform the following tasks:

(1) Perform an adequate, comprehensive evaluation of a water supply system,

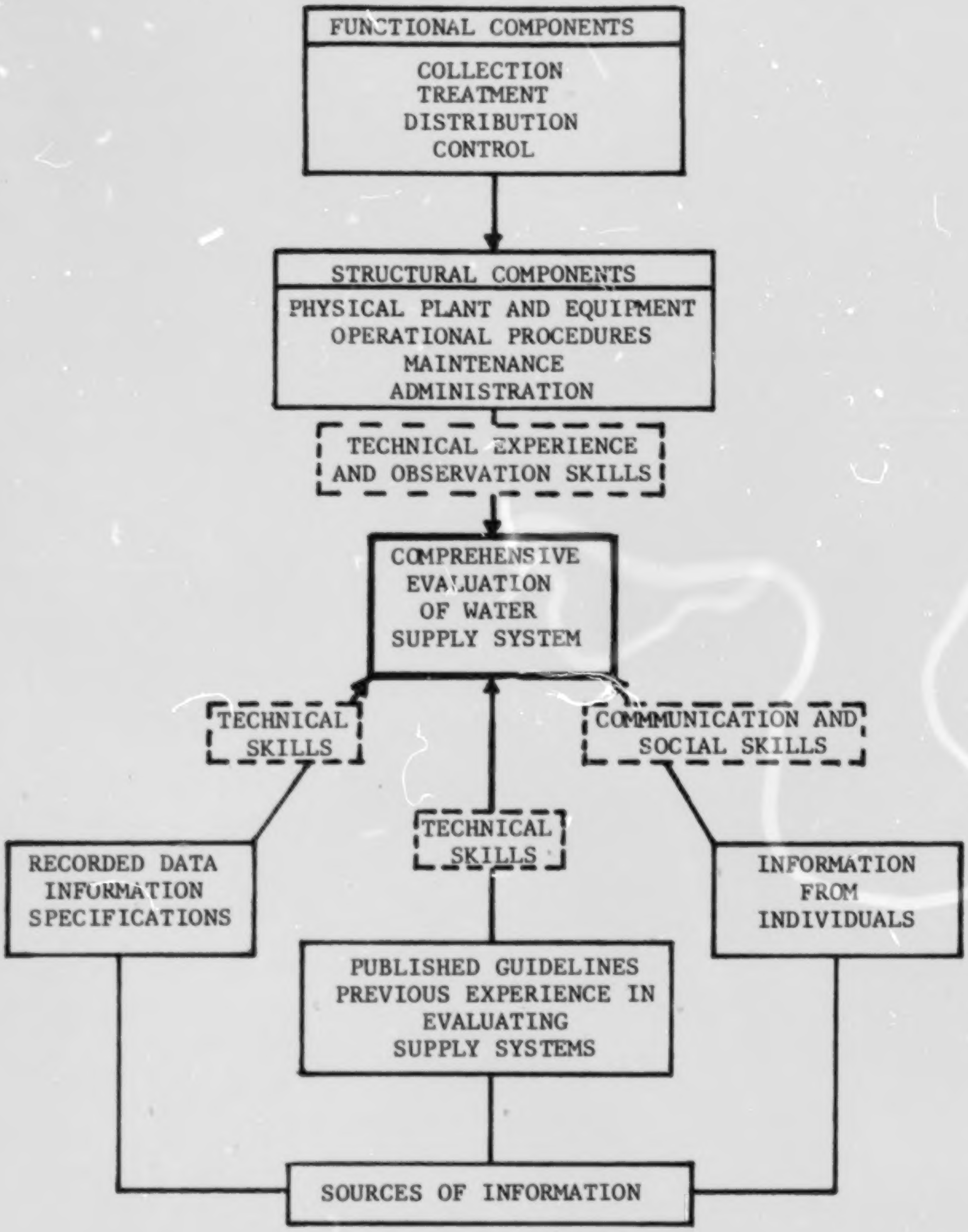
FUNCTIONAL COMPONENTS
COLLECTION
TREATMENT
DISTRIBUTION
CONTROL
STRUCTURAL COMPONENTS
PHYSICAL PLANT AND EQUIPMENT
OPERATIONAL PROCEDURES
MAINTENANCE
ADMINISTRATION
TECHNICAL EXPERIENCE AND OBSERVATION SKILLS
COMPREHENSIVE EVALUATION OF WATER SUPPLY SYSTEM
TECHNICAL SKILLS
COMMUNICATION AND SOCIAL SKILLS
TECHNICAL SKILLS
RECORDED DATA
INFORMATION
SPECIFICATIONS
INFORMATION FROM INDIVIDUALS
PUBLISHED GUIDELINES
PREVIOUS EXPERIENCE IN EVALUATING SUPPLY SYSTEMS
SOURCES OF INFORMATION

FIGURE 1.1 Components of a Comprehensive Evaluation of A Water Supply System.

(2) Determine whether the information available is adequate to define the corrective actions required to improve system performance,

(3) Identify the problems that cause inadequate performance, and assign their causes among appropriate structural and functional components of the system,

(4) Analyze available data to determine the corrective procedures most likely to be effective in particular situations, and

(5) Maintain liaison among Federal state and municipal jurisdictions on the progress, intent, and limitations of inspection and technical assistance programs.

Student Workbook and Course Structure

Each student will receive a student workbook which is divided into modules. Each module describes a specific component to be considered in the evaluation of a water supply system. In most cases, a number of individual classroom and field sessions will be devoted to a single module. These classroom and field sessions have been specifically designed to give actual experience with the technical, observational, social and communicative skills required in the conduct of an evaluation. A daily schedule of these sessions will be distributed by the instructor.

A vital aspect of this course is the professional interaction between students and instructors. Each student should therefore feel free to interrupt the instructor at any time, either to ask questions, or to raise issues based upon his own interest and experience. Each student should also remember that the Student Workbook is not a text. It should be supplemented with class and field notes.

Finally, each student should satisfy himself that the objectives of the various sessions are in fact achieved by the scheduled classroom and/or field activity. These objectives are included at appropriate places in the student workbook, and will be pointed out by the instructor.

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 2

EVALUATION

TITLE OF COURSE:
CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:
EVALUATION

PURPOSE:
The purpose of this module is to describe the comprehensive nature of the evaluation, and show the student how he can use the field survey as a basic tool for the evaluation of water supply systems.

OBJECTIVES:
(1) The student will be able to define the purpose of a field survey, and to discuss its scope.
(2) The student will be able to list the structural and functional components of a water supply system.
(3) The student will be able to list general evaluation issues for the components of a water supply system.

CONTENT:

Introduction
Evaluation Process
Water Supply System Components
Evaluation Issues and the Evaluation Form

OTHER RELEVANT MODULES:

All Modules

Introduction

The sanitary survey means "an on-site review of the water source, facilities, equipment, operation and maintenance of a public water supply system for the purpose of evaluating the adequacy of such source, facilities, equipment, operation and maintenance for producing and distributing safe drinking water."[1] The evaluation process of a water supply system includes the on-site sanitary survey as well as other activities (Figure 2.1). Sources of information and data include the water supply system, the surveillance agency and other Federal and state agencies. The interpretation of data and information depends upon published guidelines and criteria, a knowledge of standard practices, and upon an understanding of principles that underlie our current knowledge of technical, scientific and social phenomena. Recommendations for corrective actions must be made with precision and conciseness.

Evaluation Process

The field survey and the report are key elements of the evaluation, but they should be viewed as part of a continuous process. This process involves data gathering, data analysis and synthesis, report writing and follow-up. The process is cyclical over a number of years. The output of previous years should become the input of the current cycle. See Figure 2.1 .

In many cases substantial information on the water supply system may be obtained prior to the actual field survey. The information may come from previous evaluation reports, and data in the agency's files or from other sources. Other sources may include Insurance Services Organization reports, U. S. Geological Survey, National Pollutant Discharge Elimination System permit reports from the U.S. EPA, demographic information from the U.S. Bureau of the Census, etc. The accumulation of all of this material prior to a field visit is important for two reasons:

(1) It helps frame important questions that may be asked during the survey.

(2) It shows the water supply system personnel that you felt the survey was important enough to be properly prepared.

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[1] U. S. Environmental Protection Agency. December 24, 1975. National Interim Primary Drinking Water Regulations. Vol. 40. No. 248. Part IV. Federal Register.

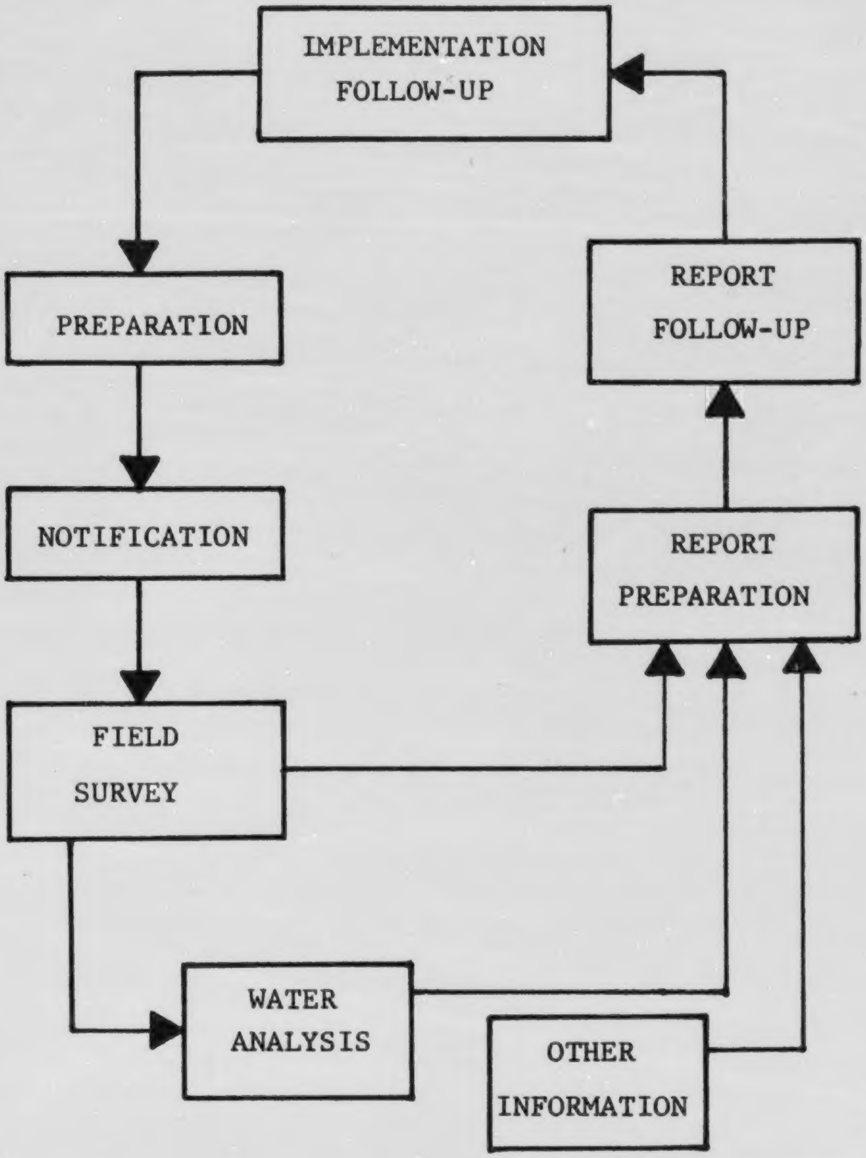
IMPLEMENTATION FOLLOW-UP
PREPARATION
NOTIFICATION
FIELD SURVEY
WATER ANALYSIS
OTHER INFORMATION
REPORT PREPARATION
REPORT FOLLOW-UP

FIGURE 2.1 The Evaluation Process.

Prior notification of an intended survey has both advantages and disadvantages. It may be important to see the system as it really operates on a normal day. This approach tends to emphasize the adversary role of the evaluator. Prior notification permits the evaluator to stress the common objective of system improvement for the benefit of the customers. It also permits the system personnel to accumulate information for the evaluator ahead of time. Agency policy and the particular supply system under consideration may dictate the best approach.

The field survey is the most important source of data. Critical to the report is the note taking at the site. The use of checklists may be helpful. In some cases detailed lists may be helpful. However, in adhering to a list, the evaluator may miss important overall issues. More general lists may be appropriate as reminders. They may be tailored to the individual system based upon the prior research. Although not all of the information will be available at the conclusion of the visit, the evaluator should give a preliminary oral report to the appropriate person at the water supply system. This is a courtesy that will assist in developing the relationship necessary for system improvement. Should the evaluator find that the final conclusions in the report will change from the preliminary, he should get in touch with the personnel and discuss the changes. The report should not be a surprise to the operating personnel with whom the evaluator dealt.

When all of the data are accumulated, it should be analyzed and the report prepared. A clear, concise, well organized report is obviously important. However, it will lose its impact, no matter how well written, if it is submitted long after the field survey. Prompt return of the report tells the water system personnel that the inspection was important and that the management must respond to the recommendations. Report completion and distribution should be accomplished within a month of the actual field survey.

The follow-up process may be handled in many ways. Policy of the evaluating agency will govern this aspect. Initially, the evaluator may call the water supply system manager to make sure he received the report, and has enough copies. He should try to elicit any questions that the manager may have and check to see if there is any disagreement with the conclusions or recommendations. If disagreement exists, the evaluator will need to devise a strategy to resolve the problem before he can expect the water supply system to act favorably on the recommendations. Should there be substantial agreement on the recommendations, the evaluator may seek a proposed timetable for compliance. This should be developed by the water supply system and will become the benchmark by which the evaluator can plan his own follow-up on implementation. Because this is a continuing process, the evaluator will find that he must provide himself with an effective filing system that ensures his attention to each system at the designated follow-up date.

The follow-up process should include a date for the next planned evaluator's survey. This ensures that the loop will be closed for each water supply system. The pressure of other concerns may make it difficult to perform the action as planned. However, the follow-up system will ensure that another date is placed on the action and that follow-up will occur.

Water Supply System Components

Water supply systems vary greatly, depending upon sources and quality of water treatment required, distributional needs and budgetary and personnel restraints. However, as shown in Figure 2.2, the system is divided into the functional components of collection, treatment, distribution, and control. The structural components of a water supply system are the building blocks of the functional components of the system. A maintenance program, for example, is a structural component of a facility that directly affects the successful collection, treatment, storage and distribution of water. Similarly, the actual collection of source waters requires specific physical equipment, operational procedures, and maintenance and administrative support to get the job done.

The structural components which support the functional components in a specific system will vary from system to system. However, it is always the evaluator's task to evaluate the following:

(1) the adequacy of each structural component in meeting its objective

(2) the capability of the component to provide continuous service

(3) safety with regard to the system and its personnel

(4) protection of the water supply quality at the component.

WATER SUPPLY SYSTEM

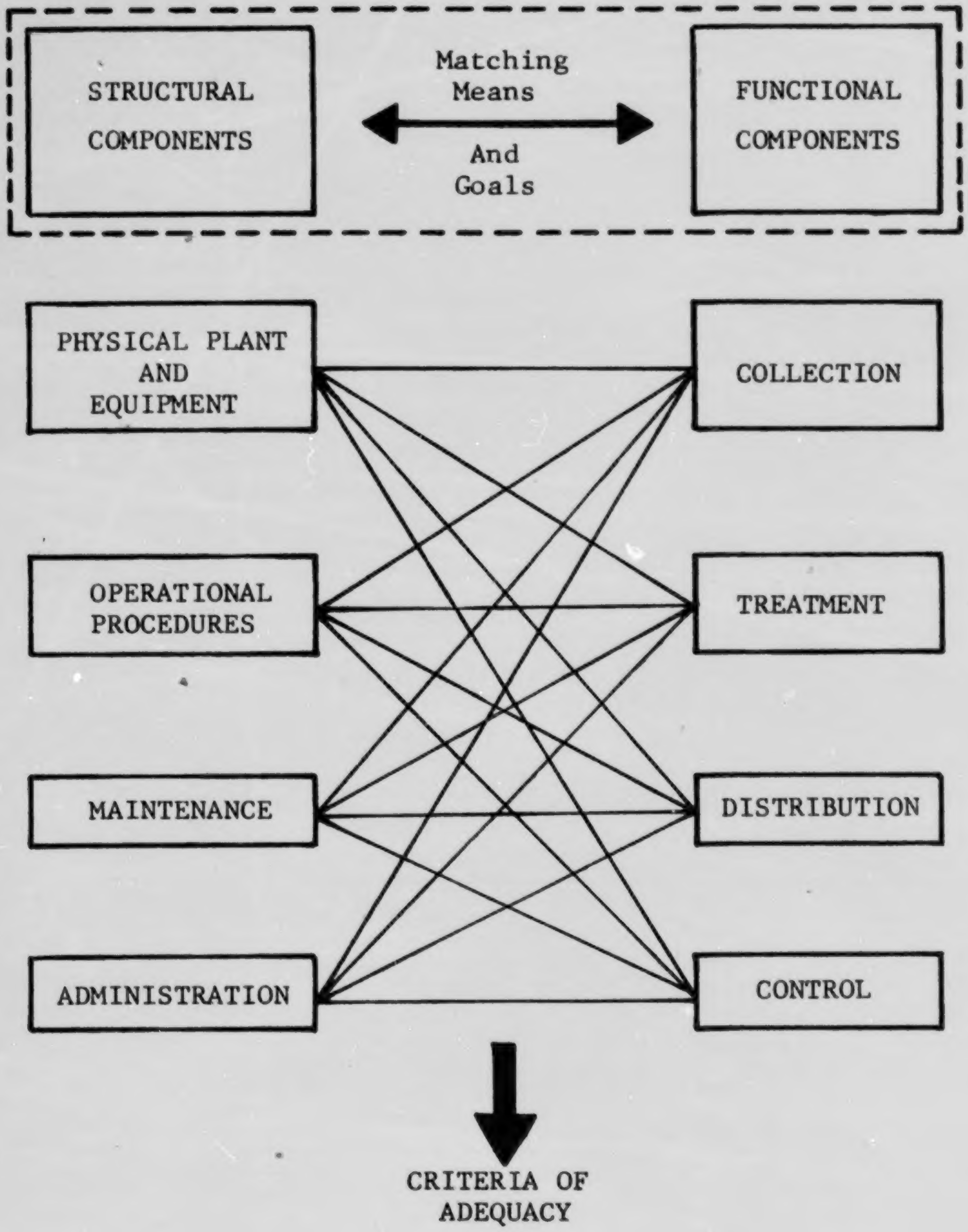
STRUCTURAL COMPONENTS
Matching Means And Goals
FUNCTIONAL COMPONENTS
PHYSICAL PLANT AND EQUIPMENT
OPERATIONAL PROCEDURES
MAINTENANCE
ADMINISTRATION
COLLECTION
TREATMENT
DISTRIBUTION
CONTROL
CRITERIA OF ADEQUACY

FIGURE 2.2 Structural and Functional Components of Water Supply System.

It is therefore essential that the evaluator be able to identify specific evaluation criteria with the various structural components of the system. For example, if an evaluator has focused on chlorination (a subfunction of treatment) and the chlorination equipment (a structural component used for chlorination) he should be immediately sensitive to a number of important evaluations that might be made. In this particular example, the experienced evaluator would probably begin to think very specifically in terms of standard practices and associated equipment for adequately accomplishing chlorination, potential problems with chemical-feed and storage, and standard operational-testing required for the effective use of that equipment. Evaluation criteria that may be employed in a field survey of the functional and structural components of water supply systems are included in the individual modules which comprise this student workbook. The relationship of these course subjects to the various structural and functional components of water supply systems is depicted in Table 2.1 .

Evaluation Issues and the Evaluation Form

This training course is not meant to provide you with a checklist of items to be evaluated at each and every water supply system that you may encounter. Attention has, however, been given to specific evaluation issues, and how these issues (both technical and non-technical) relate to specific components of a water supply system.

Of course, if any one of these issues, once identified, is going to be evaluated for its public health significance, appropriate data and information must be collected and interpreted. The following table, Table 2.2, is in a format that has been used to highlight certain of these issues with respect to the structural and functional components of a supply system. Particular sources of data, information, and guidelines that might be employed for evaluation purposes are discussed in the individual modules. These data are in addition to the brief overview provided for the evaluation criteria.

You will note that Table 2.2 could be used in the field as an evaluation form. The function, (collection, treatment, distribution or control) and the specific subfunction (well-field, impoundment, etc.) are identified including the subfunction's objective. System components are identified for the subfunction. Each component objective is stated in column 2. Column 3 is used to assure the evaluator that the system is properly managed with no component

STRUCTURAL COMPONENTS	FUNCTIONAL COMPONENTS			
	COLLECTION	TREATMENT	CONTROL	DISTRIBUTION
PHYSICAL PLANT AND EQUIPMENT	. Ground Water . Surface Water . Raw Water Storage and Transmission . Raw Water Quality and Treatment . Pumps and Pumping	. Disinfection . Raw Water Quality and Treatment . Chemical Feed and Storage . Waste Disposal	. Laboratory Testing . Cross Connections	. Pumps and Pumping . Storage . Distribution . Cross Connections
OPERATING PROCEDURES	. Pumps and Pumping . Laboratory Testing . Waste Disposal	. Treatment Processes . Chemical Feed and Storage . Waste Disposal . Laboratory Testing	. Laboratory Testing . Cross Connections . Preventive Maintenance	. Pumps and Pumping . Storage . Distribution . Cross Connections . Laboratory Testing
MAINTENANCE	. Breakdown Maintenance (All Functional Components)			
ADMINISTRATION	. Safety . Emergency Plans . Records . Management (All Functional Components)			

TABLE 2.1 Relationship of Course Subjects to Structural-Functional Components of a Water Supply System.

TABLE 2.2 Guidelines for Evaluating Public Water Supplies

Function:

Subfunction:

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion

left to fend for itself. The Evaluation Objectives are to determine (1) adequacy of the component to meet its objective, (2) safety of operation of the component to the system and system personnel, (3) protection of the quality of the water in the operation of the component and (4) capability of the component to provide continuous service. Evaluation criteria in column 5 are those pieces of data which the evaluator considers in deriving evaluation conclusions with regard to the evaluation objectives.

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 3

REPORT PREPARATION

TITLE OF COURSE:
CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:
REPORT PREPARATION

PURPOSE:
The report is the most widely visible part of the evaluation process. It is intended to identify problems and instigate action. This module is intended to assist the evaluator in developing an effective report.

OBJECTIVES:
(1) The student will be able to identify the objectives of the report.
(2) The student will be able to identify specific elements to be included in the report.
(3) The student will be able to list techniques for developing an effective report.
(4) The student will be able to outline his own report from existing data sheets.

CONTENT:

Introduction
Report Objectives
Report Elements and Organization
Some Special Issues

OTHER RELEVANT MODULES:

All Modules

Introduction

The evaluator's written report of the sanitary survey is both an end-product and a start of a new phase of the process. The field survey and written report are useful to provide a record of the water supply system status and to promote action on the part of the local water supply system. Often it is the written report alone which ends up in the hands of the ultimate decision making authority in the water supply system. The report often assumes the most important role in reaching the objective of the process - improvement of the system to meet standards. There is no one way of writing an effective report. Some guidelines may be suggested. The evaluating agency's policy will play an important role in determining the form of the report.

Report Objectives

The content and format of any written document must reflect the intent of the document. Organization, editorial style, relative emphasis of various parts are all matters which should be consistent with the objectives.

A report may be written to provide a record of an action. Chronological organization may suffice and the test of the report's effectiveness is only the accuracy or adherence to the facts. This is sometimes called a data or technical report. When new objectives are added, it becomes more difficult to organize the report. Not only must the data be presented, but it must be interpreted or evaluated. The basis of interpretation must be explained. Organization, overall length, and emphasis become important considerations if the document is to be useful to the intended reader.

As a preliminary step, we should try to agree precisely what are the objectives of the water supply evaluator's report. It will also help our report design if we know the relative importance of the objectives. Some objectives of the evaluator's report are as follows:

(1) Description of the system and its components.

(2) Identify existing inadequacies of the total system relative to water quality, continuity of supply and safety of personnel.

(3) Identify existing inadequacies in individual components relative to their objective, continuity of operation, water quality protection, and personnel and system safety.

(4) Identify potential short and long range problems that may lead to inadequacies.

(5) Instigate action to correct existing inadequacies or prevent potential inadequacies.

(6) Inform the system managers of changing regulatory requirements.

Report Elements and Organization

The objectives of the report will govern what subject matter is covered and how it will be organized. However, many practical problems arise in the reduction of the objectives to a report.

Whether a water supply is a large or small one, it is complex because it consists of both the system and its elements. Both must be dealt with in the evaluation and the report. For both the system and each element we must deal with four different aspects in the report:

(1) the description of the existing function, the facilities and the operation

(2) the criteria used for evaluation

(3) the evaluation

(4) the recommendations for action.

The description of the system, the facilities and the operation provides the baseline condition. Common agreement on this must exist before an evaluation becomes meaningful. Difficult questions arise as to the depth necessary. The use of technical language may cause problems with a lay public board responsible for the overall management. Too much detail will hurt the overall impact of the report.

The judgement as to the adequacy of the system or its component must be based upon specific generally accepted criteria. For example, finished water quality must meet minimum state standards. The report should refer to the standards that are being used. This may be by actual quotation of the standard or by reference to the appropriate manual. For some parts of the evaluation, standards will consist of good judgement such as in maintenance or management. In such cases, the standard should be described as explicitly as possible. The objective is to reach a common agreement between the evaluator and the system personnel on the criteria for evaluation. The evaluation is concerned solely with how the water supply system fares against the standards. If the description and the criteria for evaluation have been well layed out in the report, the evaluation will be easily reported.

The recommendations are concerned with the corrective action that the system should undertake. If the objective of the process is improvement of the water supply system, the recommendations for action are the key element of the report. The framing of the recomendations should be conditioned by a positive "sales" approach. The report reader must clearly understand what are the benefits of each recommended action.

The organizational difficulties for the report become apparent when we try to integrate all of these elements. Should the writer handle each of these components separately; i.e., describe the entire system, its components and operations in one section followed up by sections on evaluation criteria, evaluation, and recommendations? Or, should the writer run one part of the system through the description, evaluation criteria, evaluation and recommendation phases. There is no one way that is universally accepted. The approach chosen will depend upon desired emphasis and agency policy.

Some Special Issues

Besides the decisions on what to include and how to organize the report, a number of issues must be resolved. These include the following:

(1) What tone and phraseology should the report use? Does the report recommend or does it order certain actions?

(2) What level of technical language should be used? Who is the prime audience? Who are the prime decision-makers in that particular water supply system?

(3) Should the report contain all of the deficiencies? Should it contain only the important ones? If the deficiencies are ranked, by what criteria are they ranked?

(4) Should the report include good features of the system as well as the deficiencies?

(5) What length of report will be effective?

(6) Should the field survey sheets be included in the report?

Answers to many of these questions will be governed by the policy of the evaluating agency.

Appendix 3.1 contains several examples of evaluation reports. You should review how each of these was organized and how it handled the problems identified above.

APPENDIX 3.1

EXAMPLES OF EVALUATION REPORTS

Braun Copy

State of \ DEPARTMENT OF NATURAL RESOURCES

Secretary

August 18, 1975

IN REPLY REFER TO: 3310

Report on an Investigation of the Public Water Supply System at

The following report describes an investigation of the public water supply system at made on July 28, 1975, as part of a series of investigations of such systems in the State.

GENERAL INFORMATION

(1970 population: 672) is located in County approximately 14 miles east of The public water system is owned by the Village and it includes: two drilled wells (each of which has iron removal and zeolite softening), a 60,000 gallon elevated tank, a 100,000 gallon elevated tank, and chemical addition consisting of chlorination, fluoridation, and caustic addition. Both wells pump directly to the system with the elevated tanks providing static pressures ranging from approximately 40 to 60 psi. The average daily consumption in 1974 was 79,800 gallons, thus the 300 gpm well No. 2 pump operates approximately 4.3 hours per day. Approximately 51 percent of the distribution system water mains are 4-inch in diameter.

DISCUSSION

Well No. 1 is located in the basement of the village hall approximately 50 feet west of Spring Street and 100 feet north of South Street. The well was drilled in 1901 to a total depth of 200 feet. The 8-inch casing reportedly extends into the firm sandstone at a depth of approximately 100 feet. If the casing is not grouted (which is suspected due to the early construction date) to seal out vertical contamination and prevent corrosion of the casing, the well does not conform to present day standards. Therefore well No. 1 should be upgraded by grouting an inner casing in place or by replacing the well as soon as is practicable. A concrete pump base should be installed around the 8-inch casing in order to prevent floor drainage water from coming in contact with the well casing. A screened "U" bend well vent should also be installed at well No. 1 (a sketch is enclosed). Since the well is flowing, the vent must terminate above the artesian water level or a suitable automatic valve should be provided. A bypass piping arrangement should be considered such that when the pump is pulled the flowing water can be easily discharged. The well vent could extend from this bypass piping or from the pump base.

Pumphouse No. 1 includes an iron removal pressure filter and a zeolite softener. The existing brine storage tank is severely corroded and should be replaced. A buried gasoline tank exists approximately 20 feet north of the well. Weekly inspection of the liquid level within the tank should be made in order to determine if there is any leakage occurring. The pumphouse door presently opens to the inside; it should be remounted such that it opens to the outside in case of a main break within the pumphouse.

Well No. 2 is located approximately 150 feet north of Madison Street and 450 feet west of STH "12." The well was constructed in 1973 to a total depth of 350 feet. The 10-inch inner casing extends to the 200-foot level, while the 16-inch outer casing extends to the 130-foot level. The well is grouted to 140 feet.

Pumphouse No. 2 also includes an iron removal pressure filter and two zeolite softeners. Since the water lines to the brine storage tanks do not have air breaks, vacuum breakers should be installed on the highest point of the lines downstream from the shutoff valves.

At the time of this survey no chemicals were being added. Prior to any chemical addition all of the feeders should be equipped with anti-siphon valves (both wells) and some means of determining chemical usage should be provided (e.g. scale or graduations on solution tanks). Residual testing equipment should be available for the following tests: total chlorine, fluoride, pH, and total iron. The chemical feeders should be automatically controlled to prevent the addition of an excess amount of chemical during the backwash and regeneration cycles.

The waterworks has two elevated storage tanks. The 60,000 gallon tank is located approximately 150 feet south of STH "12" and 400 feet east of High Street. The gate on the caged ladder should be provided with a lock. The 100,000 gallon tank is located approximately 150 feet north of well No. 2. The 6-inch overflow from this tank should be provided with a concrete splash pad in order to prevent any possibility of erosion. Both elevated tanks should be equipped with smooth-end sampling taps and separate disinfection taps.

WATER QUALITY

The raw water at both wells is quite hard; well No. 1 has a total hardness of 296 ppm while well No. 2 has a total hardness of 308 ppm. Also both wells have a relatively high total iron content with well No. 1 having 0.82 ppm and well No. 2 having 1.12 ppm. The iron removal filters and the zeolite softeners are performing adequately in removing the iron and hardness.

Calculation of the Langelier Index at both wells has indicated that the treated well water has a tendency to be corrosive. Therefore, caustic soda will be added to increase the pH and thus decrease the corrosive of the water.

Further chemical addition will consist of fluoridation at both wells and a standby chemical feeder for emergency chlorination.

WASTE DISPOSAL

In order to comply with the discharge parameters and limitations set forth in the Pollution Discharge Elimination System (WPDES) permits, the backwash and regeneration wastes from the iron removal filter and zeolite softeners at well No. 2 discharge to a 42,000 gallon lagoon. The overflow from the lagoon discharges to a storm sewer and hence to the Koshkonong Creek. If freezing problems occur in the lagoon system this section should be notified. Consideration should be given to installing baffling in the lagoon near the inlet end in order to aid in the solids deposition and help prevent carry-over of suspended solids into the storm sewer overflow.

Well No. 1 backwash and regeneration wastes discharge to a marshy area approximately 500 feet from Koshkonong Creek. This discharge also will have to comply with the appropriate WPDES permit regulations and time schedules.

CROSS CONNECTIONS

There are reportedly no known cross connections between the public water supply system and any source of water of unknown or questionable safety. The waterworks operator indicated that the private well which was located approximately 30 feet from well No. 2 had been properly abandoned. The waterworks should develop and implement a cross connection control program for the detection and elimination of cross connections and for the prevention of all possible future connections.

RECORDS AND SAMPLING

The submission of bacteriological samples over the past several years has been very good, with only one "unsafe" reported in 1974. The monthly operating reports should be more thoroughly completed however. The static and pumping water levels for both wells should be recorded on a weekly basis. The iron analysis for both raw and finished water should also be recorded on a weekly basis. In order to insure that a consistent fluoride concentration is provided to the consumer, daily fluoride residual should be tested and recorded. For this purpose the Village should purchase equipment employing the SPADNS photometric technique where the result can be read immediately.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this investigation and a review of the records available, it is concluded that there are several deficiencies in the Cambridge water system that require corrective action to insure that an adequate supply of continuously safe water is provided.

1. Since approximately 51 percent of the watermain in the distribution system is 4-inch in diameter, replacing and looping with larger feeder mains should be considered.

2. That well No. 1 [illegible] be upgraded by grouting an inner casing in place or by replacing the well as soon as is practicable.

3. A concrete pump base should be installed around the 8-inch casing at well No. 1.

4. A screened "U" bend well vent terminating at least 24 inches above the pumphouse floor should be installed at well No. 1.

5. Since well No. 1 is a flowing artesian well, bypass piping should be considered such that when the pump is pulled the flowing water can be easily discharged.

6. The brine storage tank at pumphouse No. 1 should be replaced since the existing one is severely corroded.

7. Weekly testing of the gasoline levels within the buried tank outside of pumphouse No. 1 should be made to insure that there is no leakage.

8. The door at pumphouse No. 1 should open to the outside due to the possibility of a main break within the pumphouse.

9. In order to eliminate a possibility of backflow, vacuum breakers should be installed at the high points of the water lines to the brine storage tanks at both pumphouses.

10. All of the chemical feeders should be equipped with anti-siphon valves and some means of determining chemical usage should be provided.

11. Residual testing equipment should be available for the following tests: total chlorine, fluoride, pH, and total iron.

12. The chemical feeders should be automatically controlled to prevent the addition of an excess amount of chemical during the backwash and regeneration cycles.

13. The gate on the caged ladder of the 60,000 gallon elevated tank should be provided with a lock.

14. The 6-inch overflow from the 100,000 gallon elevated tank should be provided with a concrete splash pad.

15. Both elevated tanks should be equipped with smooth-end sampling taps and separate disinfection taps.

16. The parameters, limitations, and completion dates in the WPDES discharge permits should be complied with.

17. Baffling in the lagoon near the inlet end should be considered to aid in solids deposition.

18. The waterworks should develop and implement a cross connection control program for the detection and elimination of cross connections and for the prevention of all possible future similar connections.

19. The monthly waterworks operating reports should be more thoroughly completed as previously specified.

20. In accordance with Statutes, plans and specifications for all modifications or additions to the water system should be prepared by a registered professional engineer and approved by this Department prior to the installaton or construction.

Prepared by:

Public Water Supply Section

Reviewed by:

District Engineer, Southern District

JB:le
Enc.
cc: Village Clerk
Southern District
PSC
Waterworks Operator

ENVIRONMENTAL PROTECTION AGENCY

APR 8 1974

Mr. Manager
Authority of the Borough of
325 McKean Avenue

Dear Mr.

In accordance with the provisions of the Interstate Quarantine Regulations a survey of the water supply system was conducted on January 9, 1974. The Authority of the Borough of provides water to common carriers which operate interstate, and therefore, is subject to the Interstate Quarantine Regulations and the Public Health Service Drinking Water Standards.

The survey was conducted jointly with the Department of Environmental Resources represented by Ms. . The cooperation of Mr. ., Plant Superintendent, who assisted in conducting the survey is appreciated.

Attached to this letter are the major findings and recommendations resulting from our survey. Your cooperation is requested in implementing these recommendations which we believe are necessary to improve the water supply system.

The quality of water produced and delivered to customers continues to meet the Public Health Service Drinking Water Standards, and therefore, the water supply system will retain its "Approved" classification. Action on the attached recommendations will be reviewed after a one year period and the system will be classified accordingly.

If you have any questions or if we can be of any assistance, please do not hesitate to contact us.

Sincerely yours,

cc:

Regional Administrator

1 Enclosure

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OL	WSP	WSP	AW	AIR	3DA			
SURNAME	Lee	ECY	Jones	[illegible]	Manning			
	3-25-74	4/3-74	4/3/74	4/3	4/5/74			

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FINDINGS AND RECOMMENDATIONS
AUTHORITY OF THE BOROUGH OF

Laboratory Control

1. The laboratory examining the bacteriological samples for the Borough of is the Laboratory located in . The laboratory was last certified by the State on June 20, 1969.

Bacteriological examinations should be made in laboratories certified at least triennially by a State laboratory survey officer to assure the validity and reliability of the data. Requests for certification should be made to:

Mr.
Chief, Laboratory
Division of Water Quality
Department of Environmental Resources
712 Maryland Avenue

It is recommended that the Laboratory obtain a current certification as soon as possible or that the Authority of the Borough of switch to a bacteriological laboratory with a current certification.

2. A review of the bacteriological data revealed that some samples had not reached the examining laboratory within the recommended time of 30 hours. Excessive transit time is either due to poor mail service or not coordinating sample collection with the mail delivery schedule. Sampling schedules should be altered if the samples collected will be delayed by weekend or holiday mail service.

Bacterial flora may undergo marked changes in the elapsed time between collection and examination is greater than 30 hours. The examining laboratory should not accept samples greater than 48 hours old, but should telephone the Water Authority so that new samples can be collected.

It is recommended that sample collection be scheduled in a manner that will ensure delivery of bacteriological samples to the laboratory in time for examination to begin within 30 hours.

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3. Approximately 55 bacteriological samples are collected and examined monthly. Chlorine residuals are measured periodically in the distribution system but are not measured in conjunction with bacteriological sampling. It is important to measure and record the chlorine residual in conjunction with bacteriological sampling since this may provide useful information in the event unsatisfactory bacteriological results are reported. A record of chlorine residuals will provide a bank of data for comparison with future measurements to assist in operational control of the chlorination process.

It would be helpful for evaluation and control purposes to have a map of the distribution system with the sampling points marked by location. This map would prove valuable if check samples were required for the purpose of isolating a source of contamination. The map would also provide a means for determining if the present location of the bacteriological and chlorine residual sampling points provide a comprehensive coverage of the system.

> It is recommended that the chlorine residual be measured and recorded in conjunction with each bacteriological sample. It is further recommended that a map of the distribution system, with sampling points designated, be provided for proper evaluation and control of bacteriological quality and chlorine residual.

Treatment

4. Presently, the treatment plant uses a combined chlorine residual. Ammonia is injected into the raw water line as it leaves the low service pumps. Chlorine is then injected and a combined chlorine residual is formed. Post-chlorination is controlled to obtain a residual of 0.5 to 0.6 mg/l. At the time of the survey post-chlorination was not necessary since a residual of 0.5 mg/l was carried through the treatment process. The clearwells are located beneath the filters and the detention time in the clearwells is approximately 75 minutes at the present average daily flow of 6.5 million gallons per day.

Research has shown that a free chlorine residual is approximately 20-30 times more effective as a bactericidal agent than a combined chlorine residual. For this reason, in order to assure complete disinfection and to maintain a system free from bacterial growths, where combined chlorination is practiced the residual chlorine concentration should be at least 2.0 mg/l after three hours of

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contact before delivery to the first consumer. Where free residual chlorination is practiced a minimum of 0.4 mg/l should be maintained for a period of at least 30 minutes. The contact time presently provided requires that a free chlorine residual be maintained in the clearwell.

The practice of adding ammonia to obtain a combined chlorine residual at the beginning of the treatment process should be discontinued to allow the formation of a free chlorine residual in the clearwell. The discontinuance of adding ammonia at the beginning of the treatment process will also prove beneficial in the pre-treatment process since free chlorine is more effective for the oxidation of iron and manganese, and for the destruction of bacteria.

If it is still desired to carry a combined chlorine residual in the distribution system, the ammonia could be added just prior to the distribution service pump wet well. However, it should be noted that if chloramines are to be used, the desirable residual is 1.0 to 2.0 mg/l at distant points in the distribution system.

It is recommended that a minimum free chlorine residual of 0.4 mg/l be carried through the clearwell to provide adequate disinfection. It is further recommended that a minimum free residual of 0.1 mg/l or a combined residual of 1.0 mg/l be maintained at distant points in the distribution system.

5. The present pre-chlorination installation has four 150 pound cylinders manifolded into a chlorinator. Two of the cylinders are operational, with the other two to be placed into service when the on-line cylinders become depleted of gas. The post-chlorination facility is similar, but has only two cylinders; one on-line and one in a standby position. No weighing scales are provided for the gas cylinders and fresh cylinders are not placed into service until a pressure drop is observed at the chlorinators.

   The present chlorination practice results in periods where disinfection is interrupted. This occurs when the on-line cylinders become depleted of gas. The exhaustion of gas in the on-line cylinders becomes evident only when the pressure drops at the chlorinator.

   To determine the contents of containers in service, weighing scales should be provided. This would provide a record of daily chlorine usage as well as indicate when to switch to a fresh

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cylinder. The most positive and preferable method of assuring continuous chlorination is to provide an automatic switching device to change from a depleted cylinder to a fresh one.

It is recommended that weighing scales be provided to monitor chlorine usage and that procedures be implemented to assure the continuous application of chlorine without interruption.

. Ground aluminum sulfate is used as a coagulant in the treatment process. The alum is fed into a tank which is mixed by the action of the incoming make-up water. The slurry then flows from the tank through two adjustable weirs which split the flow to two sedimentation basins. At the time of the survey the alum was not properly dissolving in the mixing tank and was not being thoroughly mixed. As a result, the dosage of alum could not be accurately controlled to the two sedimentation basins and one basin was obviously receiving a higher dosage.

The effluent from sedimentation basin #2 was much less turbid than the effluent from basin #1. This could have been due to the variation in aluminum sulfate dosage, or to the difference in flow rate through the basins. The flow through basin #2 was much less judging from the depth of the water flowing over the weir. The operator stated that he directed more flow through basin #1 since it had aeration capabilities. The aeration chamber appears to be for flocculation, and if so, should be adjusted to provide a slow mix. A turbulent mix, such as that being provided with air at the time of the survey, does not promote the growth of a settleable floc.

It is recommended that the aluminum sulfate mixing process be modified to provide a thorough mix and a controlled dosage to the sedimentation basins. It is further recommended that the present practice of unequal flow distribution between the sedimentation basins, and the procedure for aeration in basin #1 be evaluated to determine the optimum operating procedure.

7. The treatment plant has 18 anthracite filters--14 with a capacity of 500,000 gpd each and four with a rated capacity of 750,000 gpd each. Filters #11 through 18 have loss of head gauges, but several are inoperable. Filters #1 through 10 have no control gauges. Presently, the filters are backwashed on a 24-hour to 30-hour cycle.

Optimum filter performance is attained through proper control of filter backwashing and length of run. The length of filter run is best determined by the continuous monitoring of effluent turbidity on each filter. The loss of head meter can also be used to determine the length of filter run and to indicate the need for filter backwashing. The rate of head loss increase during a run yields considerable information concerning the efficiency both of pretreatment and filtration.

Proper filter backwashing requires the flushing out of loose particles from the pore spaces, and agitation of the grains of the media to remove accumulated coatings. A 20 to 50 percent expansion of the filter bed is usually adequate to suspend the bottom grains. The depth of the filter media at the Charleroi plant was stated to be 48 inches. The top of the anthracite filter media was from 3 to 6 inches below the top of the wash trough. This distance is inadequate to obtain proper bed expansion during backwash without loss of filter media over the wash trough.

> It is recommended that the inoperable loss of head gauges be repaired and that some means of control monitoring be provided for filters #1-10. It is further recommended that the filter media installation be evaluated to determine optimum operating conditions during backwashing, i.e. filter bed expansion.

8. The wastes from the sedimentation basins and the filter backwash water are presently discharged to the Monongahela River without treatment. Presently, the Water Authority has no plans for treatment of these discharges.

The wastes from water treatment plants are included under Section 402 of the 1972 Amendments to the Water Pollution Control Act (P.L. 92-500) which require the issuance of a permit for all discharges. Based upon the data contained in the application, a permit requiring various degrees of treatment will be issued to the Authority. An application for a permit to discharge may be obtained from:

Mr.
Chief, Permit Programs Branch
Environmental Protection Agency
Region
6th and Walnut Streets

It is recommended that the Authority apply for a discharge permit for the wastes from the water treatment plant and comply with the requirements of that permit.

Distribution

9. The two reservoirs have a finished water storage capacity of 5 million gallons each. These are flow through basins and are open to the atmosphere. Open finished water reservoirs are subject to contamination from wind-blown debris, atmospheric fallout, birds, animals, human activities, and from deliberate contamination. The best method to prevent deterioration of the quality of water stored in reservoirs is to provide watertight storage facilities that are constructed with roofs to protect against contamination. The disinfection mechanism is hindered by the presence of turbidity and debris introduced into these open reservoirs, and exposure of the chlorinated water to the atmosphere can cause much of the residual to be lost through reduction by sunlight and evaporation.

The combined capacity of the two reservoirs is 10 million gallons which results in detention times of over 36 hours. Under these conditions it is difficult to maintain a chlorine residual through the reservoirs, especially during the summer months.

It is recommended that the Reservoirs be provided with an adequate cover to protect against contamination. As a minimum until a cover is provided, it is recommended that facilities be provided to chlorinate all water re-entering the distribution system from the open finished water reservoirs.

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DEPARTMENT OF HEALTH

December 10, 1970

Village Council of Valley
c/o Mr. Administrator
Village Hall
Cedar Avenue

COPY

Gentlemen:

We are enclosing a copy of the report of our district office covering an investigation of your municipal water supply.

If you have any questions concerning the information contained in this report please communicate with Mr. Public Health Sanitarian Department of Health.

Yours very truly,

Director
Division of Environmental Health

FFM:JLL:ew
Encl.

cc: Dr. Health Officer

Mr. Utility Supt.

Env. Health

Dist. VI

Department of Health
District [illegible]

Report on Investigation of Municipal Water Supply

October 21, 1970

Date of Last Investigation - September 21, 1964

Rating at Last Investigation - 90

Changes Since Last Investigation -

1. The Addition, Township, County has been incorporated and ownership of the municipal water supply is the Village of Valley.

2. The Addition water supply has been acquired by the Village of

3. The well has been reworked and installed with a vertical turbine pump. The pressure tank has been removed.

4. New storage facilities have been constructed which increases the storage capacity to 3,200,000 gallons.

5. The three wells in are connected to a complete system as of 1969.

6. Fluoridation equipment has been installed as of 1967.

7. Plumbing Code adopted.

8. Complete system is chlorinated.

9. Water works operators are certified.

Wells, Pumps and Pumphouses

Well No. 1, installed in April 1963, is a 16-inch by 10-inch drilled well. The well is provided with 66 feet of 16-inch steel pipe drift casing and 445 feet of 10-inch steel liner pipe which extends approximately 15 feet into the Jordan sandstone and is grouted in place. A 16-inch open hole extends an additional 66 feet to a total well depth of 520 feet. The reported log of the well is as follows:

		Depth (Ft.)	Thickness (Ft.)
Drift	Sand	0- 23	
	Sand & gravel	23- 38	
	Limerock slab	38 41	
	Clay & gravel	41- 51	51
Platteville	Limestone	51- 78	
	Shale	78- 93	42
St. Peter	Sandstone	93-243	155
Shakopee-Oneota	Dolomite	248-428	180
Jordan	Sandstone	428-520	92

Water is drawn from the well by means of a water-lubricated vertical turbine pump which is rated at approximately 515 gallons per minute and powered by a 50 horsepower electric motor. The well has been provided with properly constructed casing and discharge vents. The pumphouse is constructed with the concrete floor entirely above ground level. The pumphouse has been provided with two doors, one of which opens outward and the other is of the overhead garage type. The floor drain, which is connected to an extra-heavy cast-iron pipe, discharges to a gravel pocket approximately 50 feet from the well. A corner of the pumphouse has been enclosed to provide a separate room for the chlorination equipment. This room has been provided with a separate door to the outside and mechanical ventilation.

Well No. 2, installed in February 1964, is a 24-inch by 16-inch drilled well. The well is provided with 73 feet of 24-inch steel pipe drift casing and 431 feet of 16-inch steel liner pipe which extends approximately 15 feet into the Jordan sandstone and is grouted in place. A 23-inch open hole extends an additional 93 feet to a total well depth of 529 feet. The reported log of the well is as follows:

		Depth (Ft.)	Thickness (Ft.)
Drift	Sand & gravel	0- 72	72
Platteville	Limestone	72- 87	
	Shale	87- 98	25
St. Peter	Sandstone	97-250	153
Shakopee-Oneota	Dolomite	250-416	166
Jordan	Sandstone	416-529	113

Water is drawn from the well by means of a water-lubricated vertical turbine pump which is rated at approximately 925 gallons per minute and powered by a 100 horsepower electric motor. The static water level is reported to be 84 feet and the draw down approximately 49 feet at a pumping rate of 925 gallons per minute. The well has been provided with a properly constructed discharge vent and a screened casing vent, the opening of which faces upward. The pumphouse is constructed with the concrete floor entirely above ground level and provided with one door which opens outward. The floor drain, which is connected to an extra-heavy cast-iron pipe, discharges to a gravel pocket approximately 50 feet from the well. A corner of the pumphouse has been enclosed to provide a separate room for the chlorination equipment. This room has been provided with a separate door to the outside and mechanical ventilation.

Well No. 3, which was the Additional well, has been reconstructed in 1969. It is now a 20-inch by 12-inch drilled well. The well is provided with 122 feet of 20-inch steel pipe drift casing and 476 feet of 12-inch steel liner pipe which extends approximately 15 feet into the Jordan sandstone and is grouted in place. 90 cubic yards of sandstone has been removed to extend the well to a total depth of 584 feet. The reported log of the well is as follows:

	Depth (Ft.)	Thickness (Ft.)
Glacial Drift	0-121	121
Platteville	121-167	46
St. Peter	167-277	100
Shakopee	277-461	184
Jordan	461-584	123

Water is drawn from the well by means of a water-lubricated vertical turbine pump which is rated at 1200 gallons per minute and powered by a 150 horsepower electric motor. The static water level is reported to be 194 feet and the draw down approximately 32 feet at a pumping rate of 1200 gallons per minute. The well has been provided with a properly constructed discharge vent and a screened casing vent. The pumphouse has a concrete floor entirely above ground level and has a door which opens outward. The floor drain which is connected to an extra-heavy cast-iron pipe discharges to a gravel pocket greater than 30 feet from the well. A corner of the pumphouse has been enclosed to provide a separate room for the chlorination equipment. This room has been provided with a separate door to the outside and mechanical ventilation.

Analytical Data - (see attached sheet)

Samples Nos. 3051-3056, inclusive, represent water collected from the wells and three points on the distribution systems. The bacteriological examination of the samples show the water to be of satisfactory sanitary quality as evidenced by the fact that organisms of the coliform group were not found.

The chemical examination showed the water to be low to moderately high in iron and very low in manganese and nitrate nitrogen. Surfactant, a constituent of household detergents, was not found in a determinable amount. The fluoride concentration from the three points on the distribution system showed a range from 0.9 to 1.2 milligrams per liter which is in the range of 0.9 to 1.5 milligrams per liter recommended for control of dental caries (tooth decay).

Tests made during the course of the investigation showed that an effective chlorine residual was being maintained on the distribution system.

Recommendations -

1. The exhaust ventilation system should be extended to within 6 inches of the floor in the chlorination room.

2. Arrangements should be made for the routine collection and bacteriological examination of samples from the wells and distribution system on at least a monthly basis and a permanent record of these results maintained.

3. Attendance at the annual Water Works Operators' School, held at the Center for Continuation Study, University of is a valuable experience for anyone engaged in this field.

Conclusion

The field survey showed this supply has a relatively high degree of sanitary safety at this date. Computed on the basis of 100 points for complete compliance with the standards of this Department, the present status of this supply is estimated to be 93. As indicated, this rating may be raised to 96 by carrying out the above recommendations.

Public Health Sanitarian

Approved:

Chief
Section of Water Supply and
General Engineering

DEPARTMENT OF HEALTH

Section of Water Supply and General Engineering

Sanitation Safety Rating of Village of [illegible] Water Supply

Date October 21, 1970

	Perfect Score	As Found	As Recommended	See Recommendation No. In Attached Report
(A) Source				
Sanitary Safety Adequacy of treatment	20	20	20	
Bacteriological Quality	10	10	10	
Physical quality	2	2	2	
Chemical quality	4	2	2	
Biological quality	2	2	2	
Adequacy of quantity	2	2	2	
Sub-total	40			
Hazard adjustment factor deducted	0			
Total	40	38	38	
(B) Prime Moving Equipment				
Well or intake	8	8	8	
Pumps	7	7	7	
Piping arrangement	5	5	5	
Reservoirs	7	7	7	
Equipment housing	3	2	3	1
Sub-total	30			
Hazard adjustment factor deducted	0			
Total	30	29	30	
(C) Distribution System				
Street mains	5	5	5	
Building services	2	1.5	1.5	
Plumbing	3	2.5	2.5	
Hydrants	1	1	1	
Storage	4	4	4	
Pressure	2	2	2	
Tap water quality	3	3	3	
Sub-total	20			
Hazard adjustment factor deducted	0			
Total	20	19	19	
(D) Operation and Operators				
Control of system	3	1	2	2
Condition of system	2	2	2	
Operator qualifications	5	4	5	3
Sub-total	10			
Hazard adjustment factor deducted	0			
Total	10	7	9	
GRAND TOTAL AND RATING	100	93	96	

90 and upward - high degree of safety. Watchful maintenance needed.

85 to 89 - moderately high degree of safety. Correction and maintenance program continued.

70 to 84 - poor to dangerous condition. Prompt corrective action urgently needed.

69 and lower - very dangerous condition. Emergency measures necessary.

JB

DEPARTMENT OF HEALTH
DIVISION OF ENVIRONMENTAL HEALTH

ANALYTICAL DATA

Samples Collected By ____________ ____________ Report To District VI

Field Number	Town, County, Etc.	Sampling Point and Source of Sample		
	County	Well #1	P.D.	M.W.S.
	"	Well #2	P.D.	M.W.S.
	"	Well #3	P.D.	M.W.S.
d	"	Westview Elem. School	S.T.	M.W.S.
e	"	157 Cimmeron	H.B.	M.W.S.
f	"	Village Hall	S.T.	M.W.S.

This line for Lab. use only.	a	b	c	d	e	f
Sample Number	3051	3052	3053	3054	3055	3056
Date Collected	10/21/70	-----	-----	-----	-----	-----
Time Collected						
Temperature °F						
Date Received by Lab.	10/21/70	-----	-----	-----	-----	-----
Coliform group organisms: M.P.N. per 100 ml.	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2
Coliform group organisms: Con. ☐ Comp. ☐						
Coliform group organisms: M.F.C. per 100 ml.						
Total Solids						
Turbidity						
Color						
Total hardness as $CaCO_3$						
Alkalinity as $CaCO_3$						
pH value						
Iron	0.49	0.63	0.47			
Manganese	0.05	0.04	0.04			
Chloride						
Residual Chlorine				0.4	0.7	0.5
Sulphate						
Fluoride				0.9	1.1	1.2
Total Phosphorus						
Nitrite Nitrogen						
Nitrate Nitrogen	<1	<1	<1			
Methylene Blue Active Sub. as ABS	< .1	< .1	< .1			
Calcium as $CaCO_3$						
Sodium						
Potassium						
Spec. Cond. µmhos/cm @ 25 °C						
pHs @ 50 °F						

< : less than

REPORT

on a

JOINT SURVEY

at

On August 5, 1976, the U.S. Environmental Protection Agency (U.S. EPA) and the Illinois Environmental Protection Agency (IEPA) conducted a joint survey of the Supply. The following individuals were present during the inspection:

Mr.	Operator, Public Water Supply
Mr.	Superintendent of Public Works, Village of
Mr.	Environmental Engineer IEPA, Aurora, Illinois
Ms.	Environmental Engineer U.S. EPA, Region V Chicago, Illinois
Mr.	Staff Engineer U.S. EPA, Region V Chicago, Illinois

The inspection was relevant to certifying the Water Supply to serve water to facilities serving interstate carriers. Drinking water from the system is taken on board barges involved in interstate commerce at the Dock.

CERTIFICATION

The Water Supply is certified "Provisionally Approved (Bacteriological Monitoring)" for supplying water to interstate carriers. This certification means that the utility is judged capable of serving safe quality drinking water but that bacteriological sampling frequency has been inadequate. Specifically, submitted no distribution system water samples for bacteriological analysis during September, 1975, and March and May, 1976.

This certification may be revised when results of twelve months of satisfactory bacteriological monitoring are available.

OBSERVATIONS AND RECOMMENDATIONS

1. No samples were submitted for bacteriological analysis in September, 1975, March and May, 1976. Regular bacteriological testing of distributed water is necessary to document that no pathogenic organisms are likely to have been present. This monitoring also assists the detection of sanitary

defects in the system. Both the 1962 Public Health Service (PHS) Drinking Water Standards and the Interim Primary Drinking Water Regulations (effective June 24, 1977) require at least two monthly samples from the distribution system.

It is therefore recommended that at least two distribution system samples be collected for bacteriological analysis during each calandar month. Because of the high number of transients using drinking water, more frequent sampling is desirable.

2. It is noted that no emergency power is provided for the Harlem Avenue Pumping Station. Emergency power should be provided for all system facilities in order to assure that a continuous, safe quality, drinking water is available to consumers.

It is therefore recommended than an emergency power supply be provided for the Harlem Avenue Pumping Station. Possible alternatives include power lines from two seperate power sub-stations or an on-site emergency generator powered by an independent fuel source.

3. Limited Village resources prevent cross-connection inspections of all but new services. Cross-connection control on existing services consists of educating local industries through periodic mailings that outline potential cross-connection hazards. Industries are also asked to inspect their facilities for cross-connections.

The system's relatively large number of industrial connections represents a high potential for cross-connections. It is therefore recommended that the utility expand its cross-connection control program. The expanded program may include ranking industrial connections according to hazard, educating plant engineers on detection of cross-connections, and ultimately, Village inspections for cross-connections at hazardous services. Educating industries of the cross-connection hazard is a necessary first step to eliminate cross-connections. The next step should be to rank services according to degree of hazard. This would provide a basis for conducting on-site plumbing inspections when resources become available.

4. Chlorine gas could pass through the floor of the chlorine room in both pumping stations to the unventilated pipe gallery below. At Central Pumping Station a hole was left when chlorination equipment was changed. At the Harlem Avenue Pumping Station an electrical conduit through the

floor is not sealed. In either case, workers in the pipe gallery could be exposed to leaking chlorine gas.

It is therefore recommended that the chlorine room at each pumping station be completely sealed from the rest of the building.

5. Chlorine is applied as water is pumped from the reservoir to distribution. This practice provides a chlorine contact time much shorter than the recommended minimum for effective disinfection of 30 minutes before water reaches the first customer. It was also reported that chlorine residual entering the reservoir is near zero. This is inadequate to protect stored water from contamination.

It is therefore recommended that chlorine also be applied as water from Chicago enters the reservoirs. This would both protect stored waters from contamination and provide chlorine contact time to assure complete disinfection prior to use by the customer nearest the pumping station.

DESCRIPTION OF WATER SYSTEM

purchases water from Chicago. The agreement for the Chicago water supply limits pumpage to that shown below:

	Average (mgd)	Maximum (mgd)
1976	11.475	18.360
1977	11.780	18.840
1978	12.055	19.288
1979	12.330	19.728

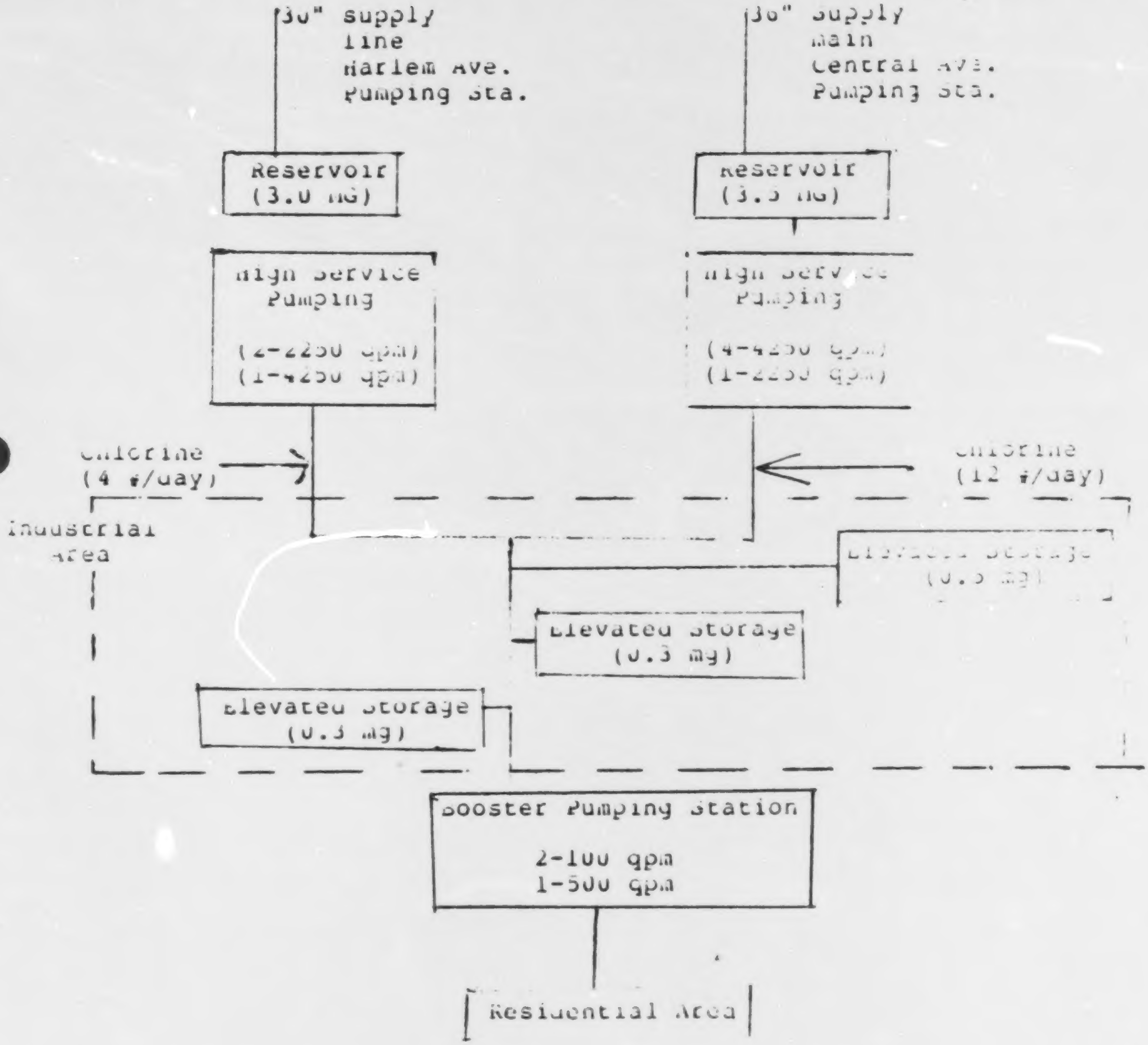
Water is provided to a permanent population of 600 and approximately 50,000 transients that work in local industries. Water is served through 687 connections (2 commercial, 475 industrial, 200 private, and 10 public). Only the "industrial" connections are metered.

The water supply employs two operators with Class C water treatment plant operator certificates.

Physical water treatment facilities are described in the Appendix to this report. A flow diagram of the Water System is shown in Figure 1.

Figure 1

Flow Diagram


30" supply line Harlem Ave. Pumping Sta.
36" Supply main Central Ave. Pumping Sta.
Reservoir (3.0 MG)
Reservoir (3.5 MG)
High Service Pumping (2-2250 gpm) (1-4250 gpm)
High Service Pumping (4-4250 gpm) (1-2250 gpm)
Chlorine (4 #/day)
Chlorine (12 #/day)
Industrial Area
Elevated Storage (0.5 mg)
Elevated Storage (0.3 mg)
Elevated Storage (0.3 mg)
Booster Pumping Station 2-100 gpm 1-500 gpm
Residential Area

QUALITY CONTROL

Bacteriological

The PHS 1962 Drinking Water Standards require that a community serving 600 permanent residents obtain two monthly samples for bacteriological analysis. Bacteriological sampling in each of the past 12 months is summarized in Table I.

No samples showed the presence of coliform bacteria.

Samples are collected at random throughout the distribution system and are analyzed by the IEPA Laboratory in Chicago. This laboratory was last approved on November 13, 1974.

Chemical

Water samples for complete chemical analyses were collected at Central Pumping Station. As shown in Table II, this sample met all chemical limits established by the 1962 PHS Drinking Water Standards and the Interim Primary Drinking Water Regulations.

Chlorine Residual

Chlorine residual is checked continuously at the Central Pumping Station. The utility checks the automatic recorder for accuracy daily and checks chlorine residual daily at the Harlem Avenue Pumping Station. Chlorine residual is also checked when bacteriological samples are collected and occasionally at points in the distribution system. Free chlorine residual was measured at 0.5 mg/liter at Central Pumping Station during the joint survey. Chlorine residual was also checked at Harlem Avenue Pumping Station, the Booster Pumping Station at 65th and Archer, and at Gatex where free chlorine residuals of 0.4 mg/liter, 0.4 mg/liter, and <0.1 mg/liter were measured. The low chlorine residual at Gatex was probably because the sample was collected at the end of a dead end main. Records of distribution system chlorine residuals showed 0.2 - 0.7 mg/liter free chlorine residual.

Table I Bacteriological Sampling

Month	Number of samples	Month	Number of samples
August 1975	6	February 1976	6
September 1975	9	March 1976	6
October 1975	6	April 1976	12
November 1975	6	May 1976	9
December 1975	6	June 1976	12
January 1976	6	July 1976	5

Table II CHEMICAL ANALYSIS

Turbidity (5 S.U.)	0.12	Specific Conductance (micromohs at 25 degrees C)	263.
Color (15 S.U.)*	2.	pH	7.75
Total Disolved Solids (500)*	167.	Chromium (Cr^{+6})(0.05)**	<0.005
Chloride (250)*	12.	Silver (0.05)**	<0.05
Nitrate (45)*	1.	Copper (1.0)*	<0.02
Lithium	<0.01	Lead (0.05)**	<0.005
Barium (1.0)**	<0.2	Iron (0.3)*	<0.1
Arsenic (0.01)*(0.05)**	0.0075	Cadmium (0.01)**	<0.00
Sulfate (250)*	25.	Zinc (5.0)*	<0.02
Selenium (0.01)**	<0.005	Mercury	<0.00
Fluoride (1.4 - 2.4)**	0.9	Cyanide (0.01)*(0.02)**	<0.02
Manganese (0.05)*	<0.05		
Sodium	4.4		

* Recommended Limit

** Mandatory Limit

NOTES: 1. All items measured in mg/liter unless otherwise noted.

2. Sample collected at the Central Pumping Station, on August 5, 1976, by the U.S. EPA.

CROSS-CONNECTION CONTROL

inspects only new services for cross-connections. The utility periodically sends letters to each industrial connection outlining the hazards of cross-connections and requesting the customer to conduct an in-house plumbing inspection. In addition, the Village requires removal of cross-connections brought to its attention.

EMERGENCY POWER

Emergency power at Central Pumping Station consists of a 4,250 gpm gasoline engine driven high service pump, and power from two separate sub-stations. In addition, an emergency generator is provided for station lighting. The emergency engine and generator are operated weekly to assure operability.

No emergency power supply is provided for Harlem Avenue Pumping Station.

ACKNOWLEDGEMENT

The cooperation and assistance shown the joint survey team by Messrs. and is appreciated.

CONDUCTING

SANITARY SURVEYS

OF

WATER SUPPLY SYSTEMS

MODULE NO: 4

TECHNICAL ASSISTANCE

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

TECHNICAL ASSISTANCE

PURPOSE:

The purpose of this module is to discuss the broad scope of technical assistance that can be provided to water supply systems by the evaluator.

OBJECTIVES:

(1) The student will be able to list specific kinds of services that he can provide to water supply systems.
(2) The student will be able to list specific skills that he has, and specific mechanisms he can utilize in providing these services.

CONTENT:

Introduction
Products of Evaluation
Technical Assistance as a Service

OTHER RELEVANT MODULES:

Module No. 2. Evaluation
Module No. 3. Report Preparation

Introduction

While he typically performs his professional duties individually, or as a member of a small team, each evaluator is nevertheless part of an evaluation system. This system is comprised of people, knowledge, and experience. It is also comprised of specific roles for those people, for that knowledge, and for that experience in the production and maintenance of adequate and safe water supplies. As depicted in Figure 4.1, the evaluation system may be viewed as a basic means of "coupling" regulatory (Federal and state) and informational (governmental and professional) systems with the actual operation of water supply systems. The more efficient this "coupling", the greater our assurance that there will be an adequate supply and a safe supply of water for the consumer. The efficiency with which an evaluation system actually operates depends upon the technical knowledge, the communicative skills, and the attitudes of the individual evaluator.

Products of Evaluation

Perhaps the most tangible product of evaluation is the evaluation report (Module No. 3). In order to produce this report, the evaluator must integrate a variety of information, including (1) data and information on the structural and functional components of a water supply system (Module No. 2), (2) pertinent Federal, state and other guidelines and standards, and (3) his own previous experience with water supply systems and their potential problems. As important as this report is for the identification and correction of actual and/or potential public health hazards in a water supply system, the report is not the objective of an evaluation. The report should be seen, rather, as a vehicle to satisfy surveillance requirements and to provide the technical assistance to those who manage and operate water supply systems.

Examples of technical assistance which should be included in the report are:

(1) Identification of the sources of problems before the problems actually occur.

(2) General and/or specific procedural and operational recommendations which will obviate potential problems and/or mitigate existing problems.

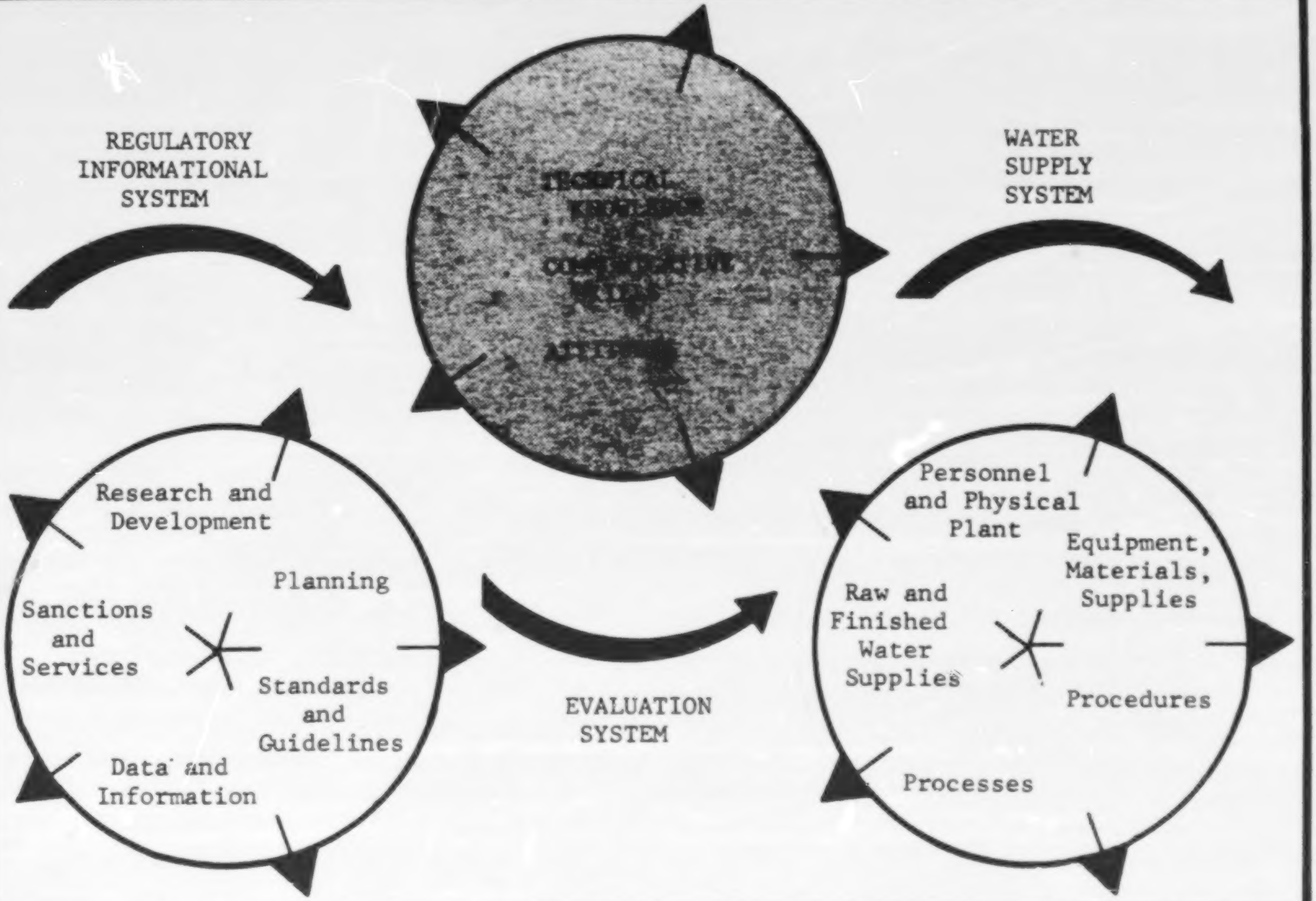

REGULATORY
INFORMATIONAL
SYSTEM
TECHNICAL
WATER
SUPPLY
SYSTEM
Research and
Development
Planning
Sanctions
and
Services
Standards
and
Guidelines
Data and
Information
EVALUATION
SYSTEM
Personnel
and Physical
Plant
Equipment,
Materials,
Supplies
Raw and
Finished
Water
Supplies
Procedures
Processes

FIGURE 4.1 Overview of Evaluation: Coupling Regulatory, Informational and Water Supply Systems.

(3) Encourage the gathering of certain data and information that might be of use to those with "trouble-shooting" responsibility.

(4) Provision of information and a communication-link between the plant and sources of information, including agencies and professional groups.

(5) Assist plant personnel to better understand their roles in the production and maintenance of potable water supplies.

While any or all of these services may be identified as being necessary or desirable in the evaluation report, they can and should be provided directly to those responsible for the daily operation of the water supply system.

Technical Assistance as a Service

Technical assistance is not an abstract. It is a service that is actually provided to people who can actually use it. Like any service, technical assistance therefore requires very specific skills and knowledge and very specific mechanisms and procedures whereby skills and knowledge can be put to work to achieve desired results. In considering his role in technical assistance, each evaluator should assure himself that he can answer these questions:

(1) Precisely what skill, piece of information or knowledge do I have that would be useful in the operation of this water supply system.

(2) To whom do I give it, and when and how do I give it?

(3) Will any follow-up action be necessary? If so, how can I ensure that such an action will be taken?

Examples of specific skills and mechanisms for providing services will be discussed in class and may be recorded in Table 4.1 .

POTENTIAL TECHNICAL ASSISTANCE PROVIDED BY EVALUATOR	SPECIFIC SKILLS KNOWLEDGE, AND RESOURCES REQUIRED	SPECIFIC MECHANISMS AND PROCEDURES REQUIRED TO PROVIDE SERVICE

TABLE 4.1 Worksheet for Identifying Potential Services By Evaluator.

CONDUCTING

SANITARY SURVEYS

OF

WATER SUPPLY SYSTEMS

MODULE NO: 5

GROUNDWATER

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

GROUNDWATER

PURPOSE:

The purpose of this module is to relate general technical issues of groundwater to the task of evaluating groundwater supplies.

OBJECTIVES:

(1) The student will be able to discuss the basic technical aspects of groundwater and its utilization.

(2) The student will be able to give examples of structural and operational aspects of groundwater supplies that should be evaluated.

CONTENT:

Introduction
Wells
Evaluation of Groundwater Supplies

OTHER RELEVANT MODULES:

Module No. 8. Pumps and Pumping
Module No. 18. Records

Introduction

The general term "groundwater" refers to the water which seeps into the ground to form a supply of water concealed beneath the earth's surface. More specifically, groundwater is that water which is found below the water table. Above the water table, in the zone of aeration, any water is held to the surfaces of rock and soil particles by capillary forces, and will not flow into a well. The water table is the top of the zone of saturation. Below the water table, in the zone of saturation, all openings -- including crevices, crannies and pores -- are completely full of water which is free to flow into a well.

Groundwater is generally considered the most satisfactory source of supply for a public water supply. The bacteriological and physical and chemical quality is usually more satisfactory than that of surface water.

The flow of groundwater below the water table depends upon the porosity and permeability of stone-soil substrate. Substrates having high porosities and permeability (e.g., sand and gravel) facilitate the flow of groundwater, and constitute important aquifers. Substrates that have relatively small and disconnected spaces (e.g., clay-silt), constitute poor aquifers. There is no necessary relationship between the porosity and permeability of substrate and depth.

An aquifer is a geologic formation situated in the zone of saturation that has sufficient transmissibility to yield water to wells in useable quantities.As indicated in Figure 5.1, groundwater may be found in two basic types of aquifers:

(1) an artesian aquifer, containing groundwater that is confined under pressure between layers of impermeable rock, and will rise to a level above the top of the aquifer when penetrated.

(2) water table aquifer, containing groundwater that is not confined under pressure.

Because of geological faults and fissures, water can escape from artesian aquifers in the form of springs. Groundwater may also flow from a water table aquifer into surface waters, including impoundments and rivers.

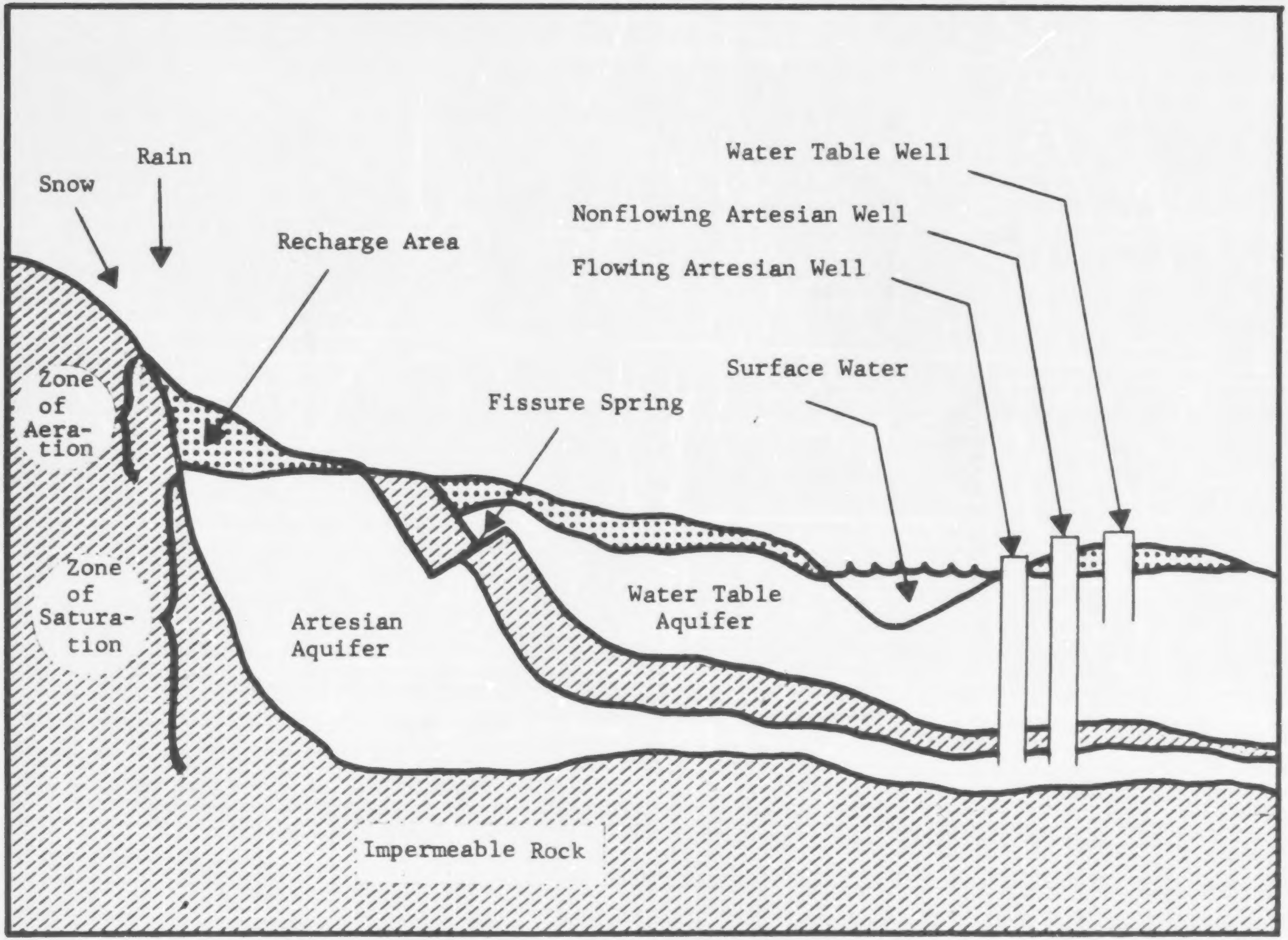

Rain
Snow
Recharge Area
Water Table Well
Nonflowing Artesian Well
Flowing Artesian Well
Surface Water
Fissure Spring
Zone of Aeration
Zone of Saturation
Artesian Aquifer
Water Table Aquifer
Impermeable Rock

Figure 5.1 Overview of Groundwater Supplies (Adapted from: U. S. Environmental Protection Agency. 1975. Manual of Individual Water Supply Systems. EPA-430/9-74-007. U. S. Government Printing Office, Washington, D.C.

A basic difference between artesian and water table aquifers is that the artesian aquifer is generally continuous over great distances, and thus its area of recharge (replenishment) may be located far away from where it might be tapped by a well. It is possible, of course, to take water out of an aquifer faster than it can be replenished by the recharge area. This phenomenon is referred to as "water mining", and can lead to the eventual depletion of stored water. Groundwater contained in water table aquifers is replenished locally, and is more immediately responsive to the local infiltration of soils by precipitation.

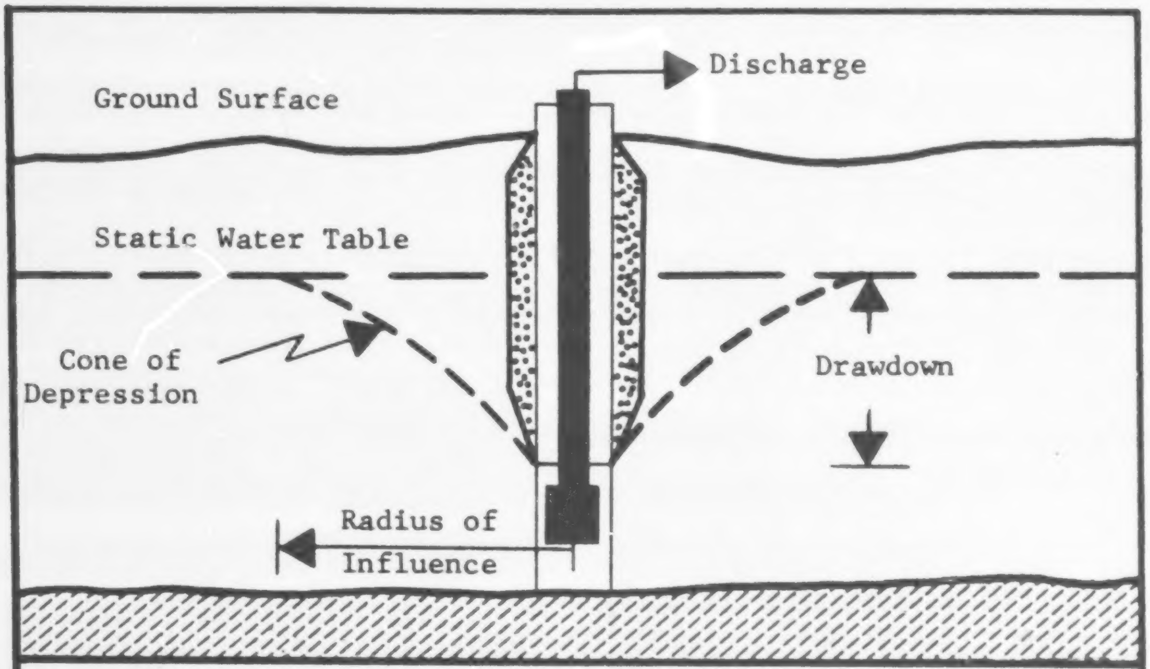
Wells

A well may be viewed as a tube inserted into the earth in order to gain access to water stored in an aquifer. During well operation, the static water level (either the water table or artesian pressure surface, depending on the type of aquifer) will be lowered in the immediate vicinity of the well. The static water level is that level to which water rises to and maintains without pumping. As depicted in Figure 5.2A, this drawdown will take the shape of an inverted cone (cone of depression) with the well as the apex of the cone. At some distance from the well, the slope of the cone of depression will coincide with the static water level.

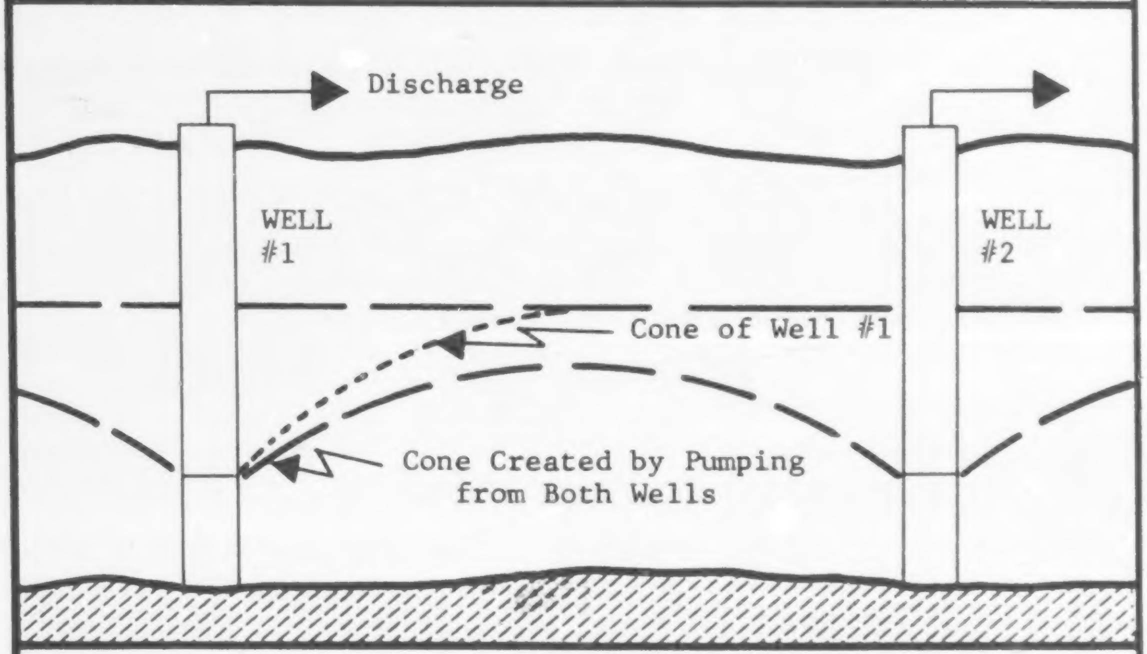
As depicted in Figure 5.2B, a number of wells may be located such that their cones of depression overlap. In such a situation, the local water table will be lowered. Pumping costs for interior wells in the field may therefore be greater than if the wells had been more widely distributed.

The specific capacity of a well refers to the rate of yield of a well per unit drawdown (e.g., gallons per minute per foot). High specific capacities indicate permeable aquifer-substrate; low specific capacities indicate less permeable aquifer-substrate, and therefore the potential need (depending on demand) for more and/or deeper wells.

Drilled wells are typically deep wells and are constructed by means of percussion or rotary hydraulic drilling. Important structural components of such wells include well casing and pipe, and setting screens or slotted casings. It is important that well casings meet accepted specifications for quality and thickness. Non-standard casing can lead to rapid corrosion and consequent shortening of useful life. An estimate of corrosiveness of groundwater is therefore requisite to good well design. Similarly, sieve


Discharge
Ground Surface
Static Water Table
Cone of Depression
Drawdown
Radius of Influence

A: Effect of Pumping on Cone of Depression


Discharge
WELL #1
WELL #2
Cone of Well #1
Cone Created by Pumping from Both Wells

B: Effect of Pumping with Overlapping Cones of Depression

Figure 5.2 Pumping Effects on Aquifers (Adapted from: U.S. Environmental Protection Agency. 1975. *Manual of Individual Water Supply Systems*. EPA-430/9-74-007. U. S. Government Printing Office, Washington, D.C.

analyses of samples of substrate are important in order to determine the size of the slot for the screen or perforated pipe installed for the purpose of obtaining sand-free water. Also, the relationship of the open area of the screen and the velocity of water through the openings is important for maximizing hydraulic efficiency.

Well point systems for driven wells, which are best suited to areas of alluvial deposits,are available in different designs. Each design has advantages and disadvantages, depending upon substrate and hydraulic conditions. Some designs are more conducive to electolytic corrosion than others. Different slot sizes determine whether a particular well will be developed properly and type and frequency of maintenance required.

Dug wells are typically shallow, are difficult to protect from contamination, and should be removed from service wherever possible. Efforts to put such wells into service should be discouraged.

Operational aspects of wells should also be considered by the evaluator. For example developing and completing are important procedures whereby formations adjacent to the well screen are disrupted and a well-graded, stabilized layer of coarse material is established around the well screen. This layer facilitates and helps to maintain the flow of water into the well.

Wells may be rehabilitated by removing incrustations of both water-bearing formations and well screens. Rehabilitative procedures may include acid treatment to remove carbonates, chlorine treatment to remove bacterial growths and slime deposits, poly - phosphate treatment to remove incrusted material in conjunction with physical surging, and physical agitation.

The appropriate treatment and/or operation of a well and water bearing formations depends upon the analysis of various records. These records may include data and information on pumping-rate and duration, drawdown, recovery time, power use, and chemical, physical and bacterial water quality. The evaluator should satisfy himself that proper records are in fact kept, are available to responsible personnel, and are actually utilized to identify and correct problems.

Evaluation of Groundwater Supplies

As depicted in Table 5.1, the evaluation of groundwater includes the evaluation of the aquifer or water table, wells, pumps and pipes and pumphouse. Each of these system components may be evaluated according to specific criteria.

For example, the recharge capability and storage variation of the groundwater supply are important criteria for evaluating the adequacy of water quantity in that supply. Similarly, the condition of the recharge area, projected future uses of the recharge area, and chemical changes associated with water withdrawal are important factors in evaluating the adequacy of water quality.

Criteria that may be applied for the evaluation of wells include the distance of the well from pollution hazards. These should be evaluated in light of state codes. The evaluator should also consider the location of wells with respect to flood levels, the seals for casing head and aquifer protection, and the proper construction of well vents.

These and other criteria for evaluating the adequacy and protection of wells, pumps, pipes and the pumphouse are summarized in Table 5.1. It is important to note that adequacy of groundwater supplies also includes the issue of continuous service.

Most of the evaluation of groundwater supplies and their use will be based on a survey of the ground surface, and a careful review of pertinent records, including routine and major rehabilitation maintenance.

TABLE 5.1 Guidelines for Evaluating Public Water Supplies

Function: Collection

Subfunction: Groundwater

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Aquifer or Water Table Description: 1. Well log 2. Other geological data known for the area	Act as a source of supply		Adequate Quality and Quantity of Supply Adequacy includes continuous service	1. Recharge capability (mining) 2. Storage variation	(Most of the evaluation of groundwater will be a survey of the ground surface, and a review of previous records of the area).
			Protection	1. Condition of recharge area 2. Future use of recharge area 3. Chemical changes with withdrawal	

TABLE 5.1 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: Collection

Subfunction: Groundwater

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Well Description: 1. Driller 2. Completion date 3. Well type . description . casing record . screen . grouting 4. Test yield 5. Water level indicator	Provide access to supply		Protection	1. Horizontal distance to pollution hazards according to state code 2. Location above flood level 3. Sealed length (Aquifer Protection) 4. Casing head seal 5. Well vent construction	

TABLE 5.1 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: Collection

Subfunction: Groundwater

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
6. Access for water level measurement			Adequacy	1. Static level 2. Drawdown, specific capacity 3. History of yield vs. present and future demand	
Pump, Piping and Appurtenances Description: 1. Pump type 2. Mounting 3. Capacity 4. Controls 5. Valves 6. Meter	Move water to distribution system or treatment plant		Continuous Service	1. Standby power 2. Maintenance records (a) Routine (b) Major rehabilitation	Satisfactory functioning to provide service

TABLE 5.1 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Collection

Subfunction: Groundwater

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Pumphouse Description: 1. Structural detail 2. Floor drainage	Protection of pump and well head		Protection	1. Location above grade for flooding 2. Proper floor drainage 3. Door, door-sill (not pit) 4. Floor drainage to surface or soil at approved distance	Satisfactory physical and sanitary protection.

CONDUCTING

SANITARY SURVEYS

OF

WATER SUPPLY SYSTEMS

MODULE NO: 6

SURFACE WATER

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

SURFACE WATER

PURPOSE:

The purpose of this module is to discuss those evaluation issues related to an adequate quantity and good quality of raw water from surface supplies.

OBJECTIVES:

(1) The student will be able to give examples of evaluation-issues that are directly related to provisions for an adequate quantity and good quality of raw water.

CONTENT:

Introduction
Inputs and Outputs
Impoundments
Running Water
Surface Water Evaluation

OTHER RELEVANT MODULES:

Module No. 9. Raw Water Quality and Treatment

Introduction

Surface waters, including natural and man-made impoundments, springs, streams and rivers, are complex physical, chemical and biological systems. The use of surface waters as public water supplies therefore requires consideration of the dynamic processes which characterize these systems, affect water quality, and present potential public health hazards.

In general, surface (also ground) waters may be divided into three groups: (1) waters useable without any treatment, (2) waters requiring disinfection only, and (3) waters requiring treatment by complete conventional means. Most surface water supplies require conventional treatment, including cooagulation, sedimentation, filtration, and disinfection. Increasingly fewer water supplies can meet current water quality standards without some type of treatment. This is due primarily to human recreational use of streams, lakes and watersheds, and to urban and industrial development.

It is essential that the evaulator utilize current water quality standards in evaluating the adequacy of on-going treatment processes (Module No. 9). It is also important that the evaluator be able to relate specific physical, chemical and biological processes in surface water supplies to potential problems in water supply systems.

Inputs and Outputs

Natural lakes and ponds, natural and man-made upstream and terminal reservoirs, rivers, springs and streams may be viewed as "machines" which receive specific inputs and discharge specific outputs. Inputs include water flow (including normal and flood flows) a variety of inorganic and organic chemicals, gases, light and heat, and different types of organisms. Potential outputs of particular importance to the evaluator include odors and tastes, disease, toxic substances, color,corrosive and filter-clogging materials and a variety of other materials that alter our aesthetic appreciation of water.

As depicted in Figure 6.1, there are four basic pathways that input materials may take in surface waters. These are as follows:

(1) Evaporation of input material to the atmosphere,

(2) Transference of input material through the supply in an essentially unchanged state,

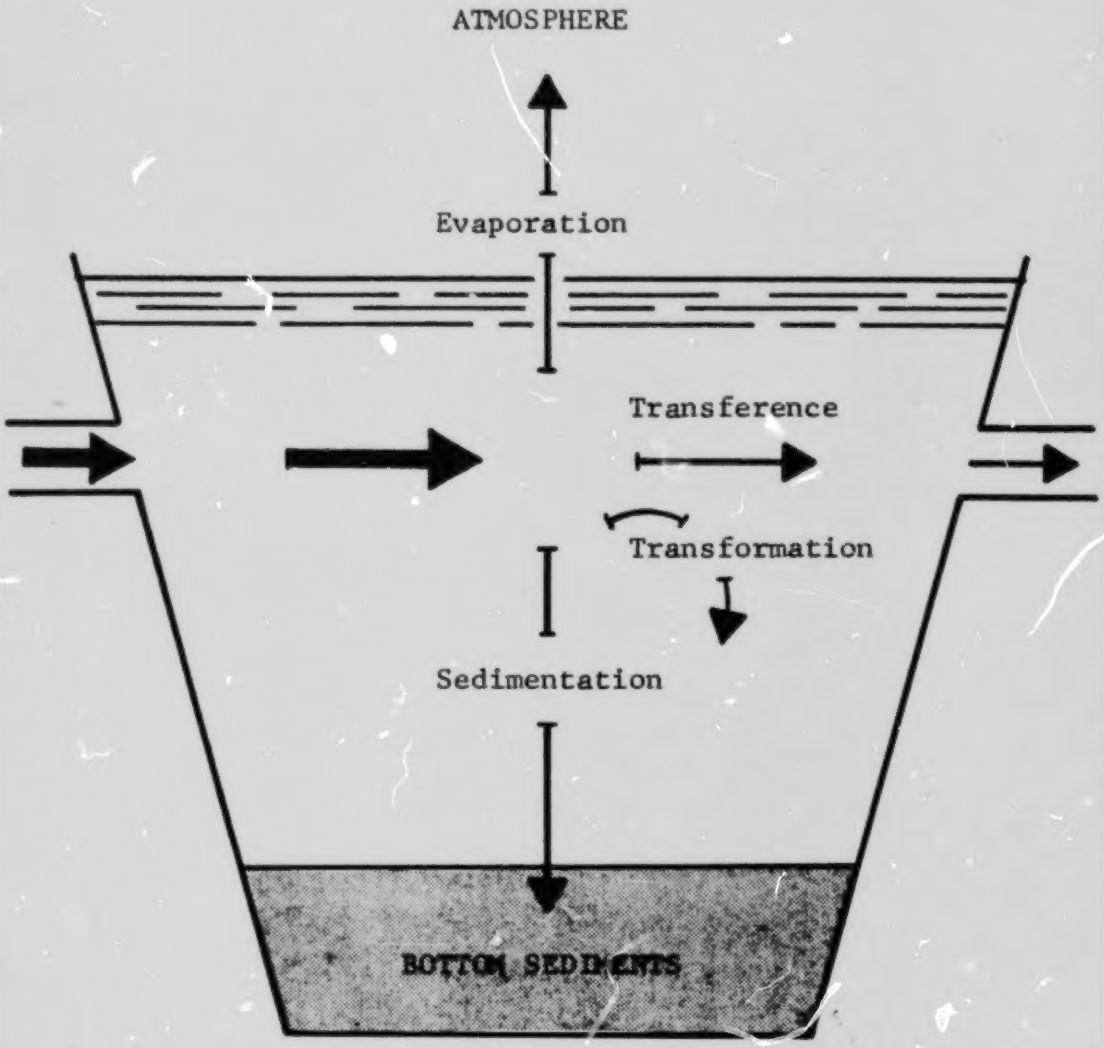

ATMOSPHERE
Evaporation
Transference
Transformation
Sedimentation
BOTTOM SEDIMENTS

Figure 6.1 Four Pathways for Input Materials in Surface Waters (Including Impounded and Running Waters).

(3) Sedimentation of input materials to bottom muds, and

(4) Transformation of input materials into other and different materials through either chemical or biological processes. Transformed materials may thence undergo evaporation, transference, and/or sedimentation.

The pathway that a particular material takes depends on the nature of the input material, and on the dynamic physical, chemical and biological processes characteristic of the supply.

Impoundments

Among the most important processes in impoundments are: photosynthesis and respiration, stratification and overturn, nutrient cycling, and energy distribution through aquatic food chains and food webs.

Photosynthesis (Figure 6.2) is carried on by macroscopic and microscopic plants (primary producers) that have the green pigment, chlorophyl. In the presence of sunlight and adequate inorganic nutrients (e.g. nitrate, phosphate) these aquatic plants produce the complex molecules which they require in order to create biomass and to maintain their life processes. The waste product of photosynthesis is oxygen. In quiescent waters, the oxygen produced by this process becomes a major supply of oxygen to aquatic organisms, including various herbivores, carnivores, and detritivores. The biomass of living plants also imparts color, taste and turbidity to the waters in which they grow.

Aquatic organisms also consume oxygen during the process of respiration. This process involves the breakdown of complex organic molecules into more simple molecules, with the subsequent release of energy and carbon dioxide. Released energy is utilized by organisms to carry on life processes. Carbon dioxide is in turn taken up by the primary producers during photosynthesis. High rates of respiration thus put a stress on available oxygen supplies, and can result in obnoxious odors, incomplete decomposition of organic materials, and the consequent build-up of bottom muds. These characteristics are typical of eutrophic impoundments, and are enhanced by the addition of plant nutrients to the water supply.

Biological transformations of input materials through photosynthesis typically occur in the upper layers of water because of the greater availability of light. Transformations due to respiration-processes are not light-dependent, and therefore occur

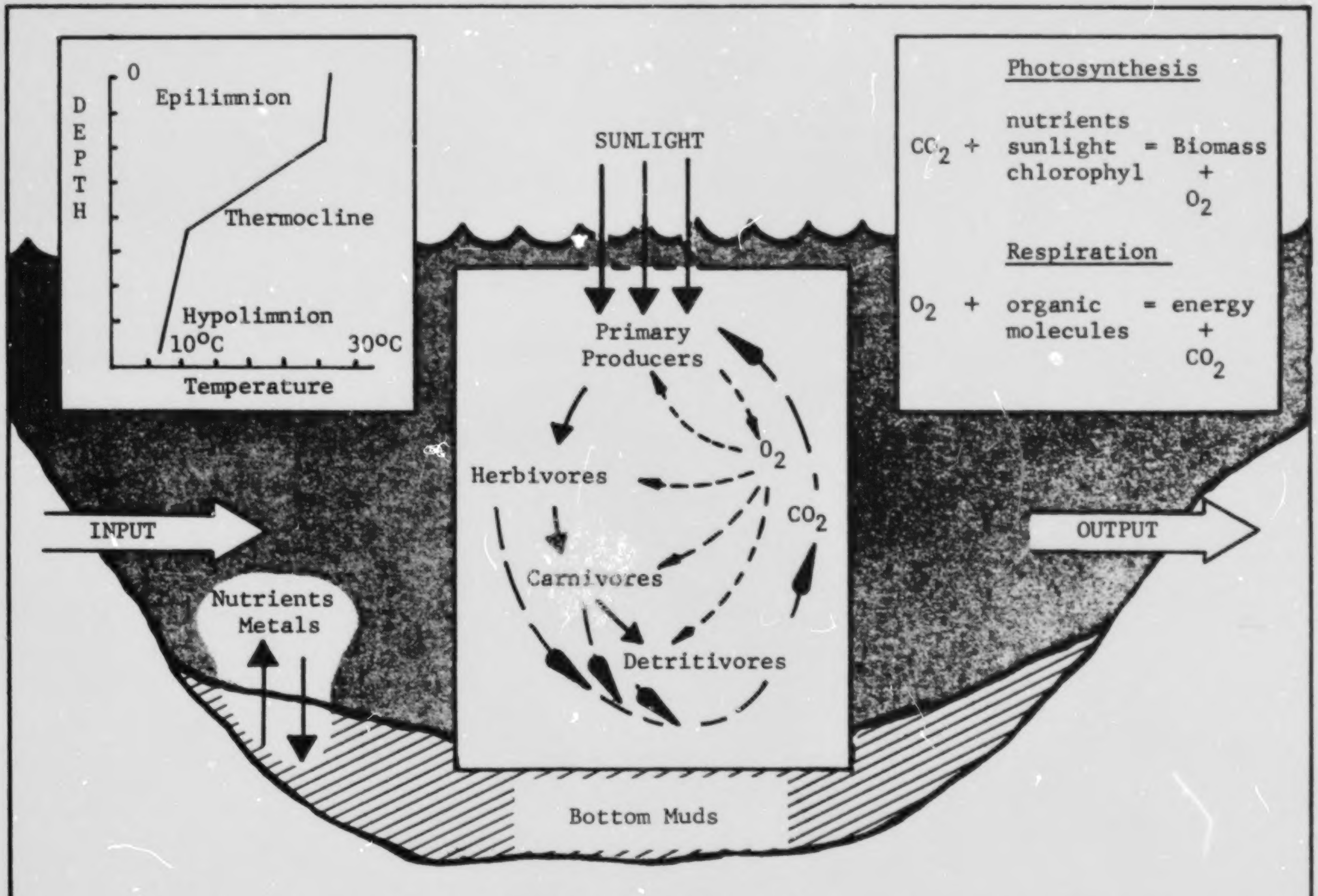

0
D E P T H
Epilimnion
Thermocline
Hypolimnion
10°C
30°C
Temperature
SUNLIGHT
Photosynthesis
CO2 + nutrients sunlight chlorophyl = Biomass + O2
Respiration
O2 + organic molecules = energy + CO2
Primary Producers
Herbivores
Carnivores
Detritivores
O2
CO2
INPUT
OUTPUT
Nutrients Metals
Bottom Muds

Figure 6.2 Some Important Physical, Chemical and Biological Processes in Surface Waters.

throughout the water column, becoming more important in bottom sediments. Bacterial respiration in these sediments releases nutrients into water. However, when impoundments stratify, nutrient rich waters are trapped at the bottom of the impoundment, and cannot contribute to primary productivity until overturn. Similarly, during stratification, little if any oxygen from the surface waters (epilimnion) diffuses to bottom waters (hypolimnion), with the result that bottom waters tend to become anaerobic.

Depending upon the morphometry of the impoundment, seasonal air-temperatures, and numerous other factors that can affect stratification, it may be necessary to tap different depths of the supply in order to avoid water quality problems associated with stagnant, anaerobic waters. Long-term complications arise because of the build-up of bottom muds. This build-up can alter the depth of stratification, and also increase the probability that metals and other potential toxic materials in muds will be transferred into intake structures.

Enhanced sedimentation of an impoundment, as well as hydrologic variations in the watershed can alter the period of time in which pathogenic organisms are subjected to dynamic aquatic processes. In general, any factor which reduces the retention-time of pathogens in impoundments increases the need for additional treatment. An evaluation of watershed characteristics, including long-term development-potential is therefore a basic tool for estimating present and future needs for proper collection and treatment.

Finally, careful attention must be given to present and projected demand and how that demand compares to safe yield. Once demand outstrips safe yield, an impoundment is not only in danger of becoming an inadequate supply in terms of quantity, but also in terms of quality. Watershed hydrology is as important as watershed development in determining the adequacy of impoundments.

Running Water

The four pathways identified in Figure 6 .1 also exist in running waters, including rivers, streams and springs. Running waters also contain a variety of primary producers, herbivores, carnivores and detritivores. One of the basic differences between running and impounded waters, however, is that the dimension of time (which is so central to the physical, chemical and biological processes in impoundments) becomes the dimension of length in running water. Thus, while organic molecules are decomposed over days and months in an impoundment, those same molecules are decomposed over miles in a river. Another important difference is that the quantity of water in rivers and streams can vary abruptly. Normal seasonal and storm variations in quantity often determine the overall quality of running water.

As organic molecules are inputted into running waters, a process of natural purification is initiated by aquatic bacteria and fungi. This process involves the decomposition (and therefore transformation) of organic materials, the distribution of decomposition products over some linear distance, and the sedimentation of these products according to hydraulic gradients along the bed. Riffles provide important oxygen inputs, speed up the decomposition process, and therefore shorten the zone of active decomposition. These also aid in the evaporation of volatile materials. Pool areas, as well as meander-banks, are important sediment traps, and serve to sequester potentially toxic materials and food supplies which in turn enhance biological productivity.

Depending on the rate of decomposition, the mineral products of decomposition are made available to downstream primary producers which, in their turn, can replenish oxygen supplies that might be severely stressed by the respiration of upstream bacterial and fungal populations.

Of course, it is extremely improbable that any running water supply will have only a single source of organic or other contamination. Urban, industrial and agricultural development along streams and rivers typically extends the zone of decomposition downstream. Isolated areas of biological productivity and sedimentation therefore occur in complex patterns. The evaluator should therefore be cognizant of the type and pattern of development along the surface-supply, how this development presently determines public health hazards at the source-intake, and how new development might produce hazards in the future. The evaluation of the location of existing intakes, the feasibility of alternative intakes along a river or stream-reach, and the availability of alternative supplies in case of accidental spills are important considerations.

Surface Water Evaluation

Impoundments should be evaluated for their adequacy in terms of both water quality and quantity, and also in terms of the protection of the supply.

Important evaluation issues pertaining to water quality include the nature of the watershed, including natural, agricultural, industrial and residential inputs that can cause water quality problems. Of course, the impoundment itself should be described in terms of its actual use. For example, is the supply used solely as a water supply, or is there multipurpose use such as boating, fishing, and swimming. Each of these activities may alter water quality by altering important physical, chemical and biological characteristics of the water. Finally, the impoundment should be described in terms of its depth and any other physical characteristics that may affect water quality and therefore present problems of water treatment.

Important evaluation issues pertaining to water quantity include the storage capacity of the watershed, variations in runoff (both short and long-term), and overflow requirement. These issues are in turn influenced by the area and shape, local precipitation, topography and surficial and bedrock geology of the watershed. Basic morphometric characteristics of the impoundment should also be evaluated for their contribution to the adequacy of the supply. Inflow and outflow volumes should also be examined to ensure that demand does not exceed safe-yield.

The protection of impoundments utilized as water supplies can be evaluated with respect to a number of issues. For example, a water supply monitoring program should be comprehensive, and ensure that samples are taken at appropriate locations and at appropriate frequencies. The evaluator should also consider watershed ownership, and how existing and potential ownership patterns may affect water quality through uncontrolled and/or changing land use. Finally, the evaluator should examine appropriate monitoring records for the purpose of identifying past problems with the water supply, the corrective actions that were taken, and the potential for future occurrences.

These evaluation issues will be discussed by your instructor and may be entered in the following Table 6.1 in your workbook. Many of the evaluation issues that are pertinent to the evaluation of impoundments are also relevant to the evaluation of rivers and streams. Your instructor will again identify the key issues for evaluating the adequacy of these supplies in terms both of quality and quantity.

With respect to protection of running water supplies, it is important to emphasize the need for a spill alert system. Spills of potentially toxic, nauseous and other obnoxious and/or dangerous materials can move swiftly and often unpredictably. A spill alert system is necessary to identify when a spill has occurred and where, and to give water supply and regulatory authorities adequate time to take corrective action. The evaluator should assure himself that the spill alert system is "fail-safe", subsequently comprehensive in design, and periodically tested. It should include contacts with up stream users, especially those using toxic materials. It may include contacts with police to ensure notification of the spills from transportation accidents. Also, water supply system operators should know their roles in any spill-alert situation precisely.

TABLE 6.1 Guidelines for Evaluating Public Water Supplies

Function:

Subfunction:

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion

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Function:

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System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 7

RAW WATER TRANSMISSION

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

RAW WATER TRANSMISSION

PURPOSE:
The purpose of this session is to discuss the adequacy of facilities used for transmission of raw water to the treatment plant.

OBJECTIVES:

(1) The student should be able to list and discuss specific issues involved in the evaluation of transmission systems.

CONTENT:

Introduction
Some General Considerations
Evaluation Issues

OTHER RELEVANT MODULES:
Module No. 6. Surface Water
Module No. 9. Raw Water Quality and Treatment

Introduction

Raw water transmission refers to the conveyance of water from its source to the point of treatment or distribution. Conveyance may be accomplished by gravity flow in an open channel or through a pipe or tunnel, or by pumped (or pressure) flow through a pipe or tunnel. The transmission system includes the intake structure, the raw water conduit and the raw water pumping facilities. In many systems, the transmission of raw water is over a short distance and may be little more than the length of a well-casing. In other systems, transmission may occur over great distances. For purposes of this module, emphasis will be given to those transmissions that occur other than in a well.

Some General Considerations

Intake structures are of various types, and each type has its advantages and disadvantages. For example, intake structures may be submerged or exposed. Submerged intake structures are typically free of problems associated with floating materials. Exposed intake structures, typically employed for the intake of large quantities of water, are less susceptible to clogging, are easier to operate and inspect, and may be utilized for taking water from different depths (i.e. multilevel intakes). Intake structures may also include wet or dry intake towers. Wet intake towers are filled with water up to the level of the source of supply, and therefore requires draining for scheduled and emergency maintenance. Dry towers are not filled with water, and provide easy access for inspection and maintenance of intake pipes which convey water from the tower under pressure.

In rivers, intakes should be protected from rapid currents which, when ice is present, can damage intake structures. Intakes should also be located in areas downstream from where major sedimentation typically occurs, and should be located so that water can be obtained at all stages of the river.

In lakes and reservoirs, intake structures should allow for the taking of water at different depths, depending on raw water quality, ice-problems, etc., and should also be located so as to be protected from shore-line erosion and other chemical, physical and biological phenomena associated with the water-land interface. Adequately designed and installed cribs and screens provide important protection from floating and suspended materials, including surface ice (i.e. floating cakes), anchor ice (i.e. on submerged gratings, valves, etc.), and frazil ice (i.e. ice crystals released from anchor ice).

The conduit from the intake should lead to either a wet well or suction well in or near the pumping station. The conduit should have sufficient capacity so as to insure that the suction of the pumps will always be submerged. Conduits may be pipes or tunnels. If the conduit is a pipe it should be held in place with piling and covered with broken stone to insure its protection from hydraulic damage.

In addition to pipe or tunnel conduits, a variety of other aqueducts may be employed in the transmission of raw water. These types include cut-and-cover sections , flumes, and earth and lined canals. Cut-and-cover sections are covered with excavated materials and offer good protection to the transmitted water. Open channeled flumes and earth and lined canals are more open to pollution. Canals also cause high seepage and evaporation losses, and are susceptible to damage by ice and burrowing animals.

Pipe conduits typically include air valves (for releasing or providing air during filling and draining), blow-off valves (for emptying sections), and gate valves (installed for cutting out sections of pipe for repair). Inspections and maintenance of all such appurtenant structures are important for the reliable functioning of the transmission system. Similarly, other types of aqueducts typically include screens (to prevent clogging), stop-planks (to shut off flow) wasteways (overflow structures in non-pressurized aqueducts), drain valves and air vents. Each of these structures should be properly installed, tested periodically and maintained.

The pumping house for raw water should be able to handle peak water demand without stress to its pumps and associated machinery. While the evaluator is not expected to evaluate the design or proper selection of prime-mover pumps, the evaluator should ensure that they are properly used and maintained, according to their specifications for priming and lubrication. Back-up equipment and power sources should be available in case of malfunction, and should be located to facilitate rapid, reliable, and safe hook-up into the mainline system.

Material inputs into raw water during transmission may occur in a number of ways, including:

(1) the abrasion, oxidation and solubilization of transmission pipe or conduit linings, surfaces , and grouts,

(2) surface runoff into open channels, and

(3) seepage and infiltration of ground and surface waters into open channels and tunneled aqueducts.

Physical, chemical and biological materials inputted into transmitted water by these means will vary greatly with region, local residental and industrial development, bedrock and surficial geology, and surficial and subsurface hydrology. Depending on these conditions as well as on the design and construction of the transmission system, water delivered to the treatment facility may be significantly different in quality from original source waters.

Finally, the length of transmission lines and the pumping rate and schedule may be such that raw water is carried for substantial periods of time in the transmission system. It is important to note that "significant time intervals" must be defined in terms of physical, chemical and biological processes, and not in terms of the human perception of time. For example, many physical, chemical and biological reactions require only seconds and minutes in order to occur. Thus, even a few hours of entrainment can result in measurable changes in various water quality parameters. Whether this will or will not actually happen in transmission systems must be evaluated on a case-by-case basis.

Evaluation Issues

As indicated in Table 7.1, the evaluation objectives of adequacy and protection must be applied to each component of the transmission system, including intake structures, the transmission line, and the low lift pumps.

A central consideration in the evaluation of each of these components is the capacity of the component vs. water demand. Demand should include peak daily demand, as well as peak demand under emergency conditions. Other determinants of adequacy of intake structures include operating parameters (e.g. the potential for water to be taken from various depths), and the location of the intake structure with respect to fluctuating water levels. The evaluator can utilize appropriate plant records in order to determine just what these water levels are, and the in-place plans for the intake structure. The evaluator should also consult maintenance records, emergency plans, and protocols and procedures for identifying and dealing with problems associated with icing, clogging, and flooding.

The protection of intake structures may be evaluated with respect to their location relative to pollution sources. The evaluator should also keep in mind potential development in upstream and/or watershed areas, and the types of pollution that might consequently affect the quality of intake-water. Flow character near the intake should also be evaluated for its potential to cause structural damage and operational interference with intake structures.

The protection of the transmission line itself should be evaluated with respect to cross connections, and consumer tap-ins to the raw water line. The protection of low lift pumps should be evaluated in terms of manufacturers' and standard practices for priming and lubrication.

In focusing on these and other issues important for the evaluation of transmission systems, the evaluator should continually remind himself of the following: while it is *generally true* that a transmission system is not the most common source of problems in a water supply system, the transmission system can cause very serious problems *in a particular water supply system*.

TABLE 7.1 Guidelines for Evaluating Public Water Supplies

Function: Collection

Subfunction: Transmission (surface water) to treatment or distribution

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Intake Description 1. Location of potential polluters on map 2. Distance from shoreline 3. Variable height 4. Screens	Draw off best quality water available		Adequacy	1. Hydraulic capa. vs. demand 2. Operating parameters (multi-level) 3. Location vs. water levels	
			Protection	1. Location vs. pollution sources 2. Flow character near intake	
			Continuous Operation	1. Maintenance records	

TABLE 7.1 Guidelines for Evaluating Public Water Supplies

Function: Collection

Subfunction: Transmission (surface water) to treatment or distribution

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
				2. Emergency plan 3. Icing, clogging, flooding	
Transmission Line Description	Transport water to treatment plant or distribution		Adequacy	1. Capacity vs. demand	
			Protection	1. Cross connection control 2. Consumer tap-ins to water line	
Low Lift Pumps - Description	Drive or draw water to treatment plant		Adequacy	1. Capacity vs. demand	
			Protection	1. Priming 2. Lubrication	See module on pumps

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 8

PUMPS AND PUMPING

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

PUMPS AND PUMPING

PURPOSE:

The purpose of this module is to provide the basic technical information for understanding the operation of various types of pumps and to develop guidelines for the evaluation of pumps used by water supply systems.

OBJECTIVES:

(1) The student will be able to explain pump operation, application and performance.
(2) The student will be able to identify the appropriate types of pumps for typical uses in water supply systems.
(3) The student will be able to define evaluation criteria for pumps.

CONTENT:

Definition of a Pump
Examples of Pumping
Basic Pump Technology and Hydraulics
Pump Types, Operation and Application
Pump Performance
Evaluation of Pumps

OTHER RELEVANT MODULES:

Module No. 7. Raw Water Transmission
Module No. 10. Treatment Processes
Module No. 11. Chemical Feed and Storage
Module No. 15. Storage & Distribution

Definition of a Pump

"A mechanical device for causing flow, for raising or lifting water or other fluid, or for applying pressure to fluids."[1]

Examples of Pumping

(1) To lift water from source to treatment processes.

(2) To discharge water under pressure to distribution system.

(3) To increase pressure in distribution system or to supply elevated storage tanks.

(4) To add chemical solutions at desired dosages to treatment processes.

(5) To pump water from sampling sources to laboratory or automated analyzers on continuous or programmed basis.

Basic Pump Technology and Hydraulics

Understanding pumps and pumping as applicable to water supply systems necessitates analysis of basic hydraulic conditions encountered in pump design and operation. These conditions can be divided into suction conditions and discharge conditions.

The most common cause of pump failure is poor suction conditions, particularly in the case of a centrifugal pump. A centrifugal pump has no capability to "suck" water and can only operate when water enters the pump under pressure, often provided by the atmosphere. This pressure is referred to as Net Positive Suction Head, NPSH. NPSH has two values; available NPSH dependent upon installation and required NPSH specified by the pump manufacturer. Available NPSH must exceed required NPSH by two to three feet or more to assure proper pump operation (Figure 8.1).

Improper suction conditions can be the cause of cavitation. This undesireable condition is caused by the formation of a cavity in the water being pumped. As the cavity moves through the pump and the pressure increases, it collapses suddenly with considerable force and will damage the pump impeller. Usually a cavitating pump is obvious from the noise produced.

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[1] AWWA, WPCF, ASCE, APHA, 1969. Glossary, Water and Wastewater Control Engineering.

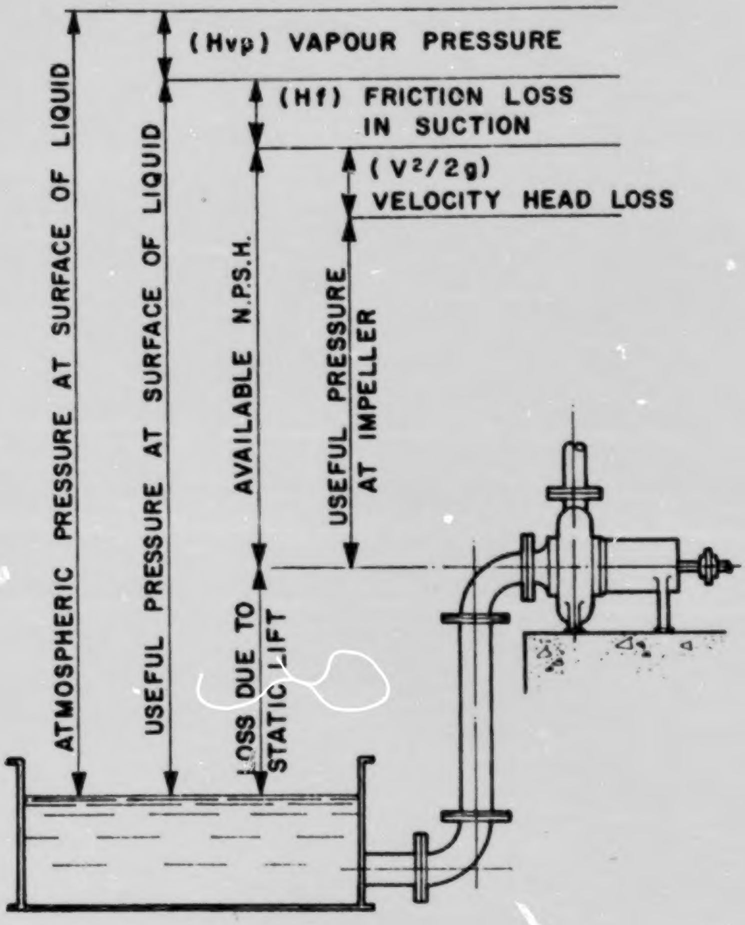
(Hvp) VAPOUR PRESSURE
(Hf) FRICTION LOSS IN SUCTION
(V²/2g) VELOCITY HEAD LOSS
ATMOSPHERIC PRESSURE AT SURFACE OF LIQUID
USEFUL PRESSURE AT SURFACE OF LIQUID
AVAILABLE N.P.S.H.
USEFUL PRESSURE AT IMPELLER
LOSS DUE TO STATIC LIFT

Figure 8.1 NPSH Centrifugal Pump. (Adapted from Walker, Rodger. 1972. Pump Selection A Consulting Engineer's Manual. Ann Arbor Science Publishers Inc., Ann Arbor, Michigan.)

Discharge conditions are those against which a pump must work or operate and consist of static head or static lift and friction head or dynamic head. Static head is the distance from the surface of the water on the suction side of the pump to the surface of the water on the discharge or pressure side of the pump. Friction head represents energy lost in overcoming the resistance to flow imposed by the intake and distribution system pipes, valves, fittings and other devices.

Total head developed by a pump is the sum of the static head and the friction head plus the velocity head. Referring to Figure 8.2, total head may be expressed:

(1) Pump with suction head

$$H = h_d - h_s + f_d + f_s + V^2/2g$$

(2) Pump with suction lift

$$H = h_d + h_s + f_d + f_s + V^2/2g$$

where $V^2/2g$ is velocity head.

Strictly speaking the velocity head developed by the pump is the difference of velocity heads at the discharge flange of the pump and the intake flange. Total dynamic head (TDH) is defined as:

> "The difference between the elevation corresponding to the pressure at the discharge flange of a pump and the elevation corresponding to the vacuum or pressure at the suction flange of the pump, corrected to the same datum plane, plus the velocity head at the discharge flange of the pump, minus the velocity head at the suction flange of the pump."[1]

The significance of TDH is that many manufacturers rate their pumps in accordance with pumping capacity at a given TDH.

A system head curve is often developed for a particular water supply system pump application and represents flow versus total head. This curve is helpful in evaluating system pumping needs and characteristics.

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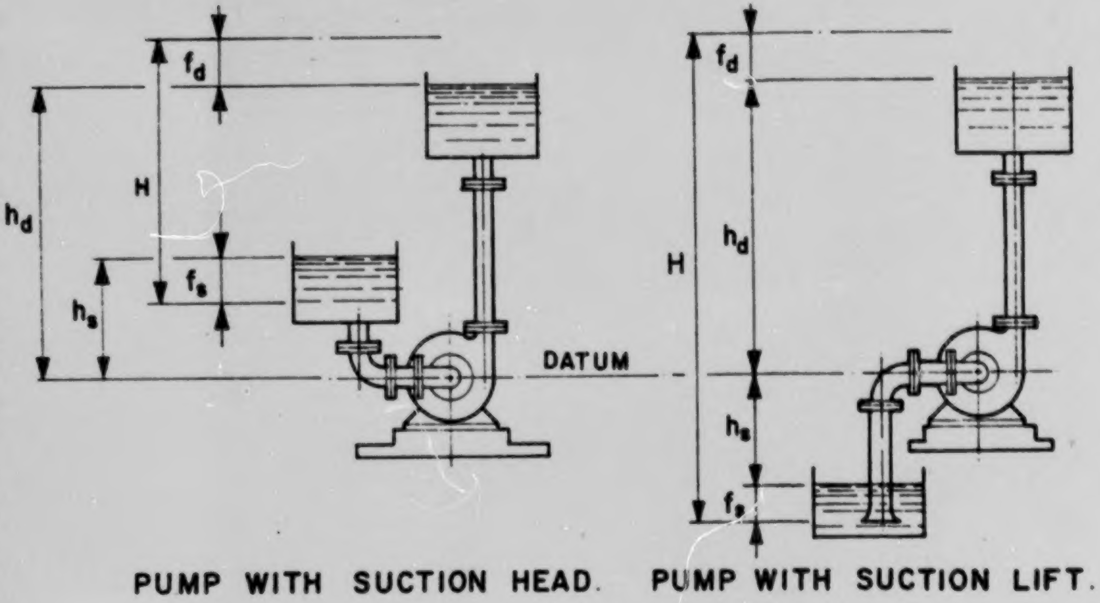
[1] AWWA, WPCF, ASCE, APHA, 1969. Glossary, Water and Wastewater Control Engineering.


f_d
H
h_d
f_s
h_s
DATUM
f_d
h_d
H
h_s
f_s

PUMP WITH SUCTION HEAD. PUMP WITH SUCTION LIFT.

Figure 8.2 Pump Heads. (Adapted from Walter, Rodger. 1972. Pump Selection A Consulting Engineer's Manual. Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan.)

Pump Types, Operation and Application

Considering pumps used in water supply systems as "prime movers" ("heart" of the system) as opposed to pumps used in treatment processes, the most common applications are to be found in pumphouses, booster stations and wells. Pumphouses or booster stations usually are equipped with either a horizontally mounted centrifugal pump or a vertically mounted turbine pump. At low flow rates and for grit free water a rotary pump may be used. Reciprocating pumps are seldom used any longer. It is important, however, to keep in mind that the discharge of a centrifugal pump varies with head and requires a variable speed drive if it is desired to maintain constant flow. Alternatively, the discharge of a reciprocating or rotary is dependent upon speed alone.

Wells are most commonly equipped with vertical turbine or submersible pumps. Reciprocating pumps may occasionally be found on older facilities. An air-lift pump is rare enough to be considered a special case. Ejector or jet pumps are used extensively for low volume flows such as private residential wells.

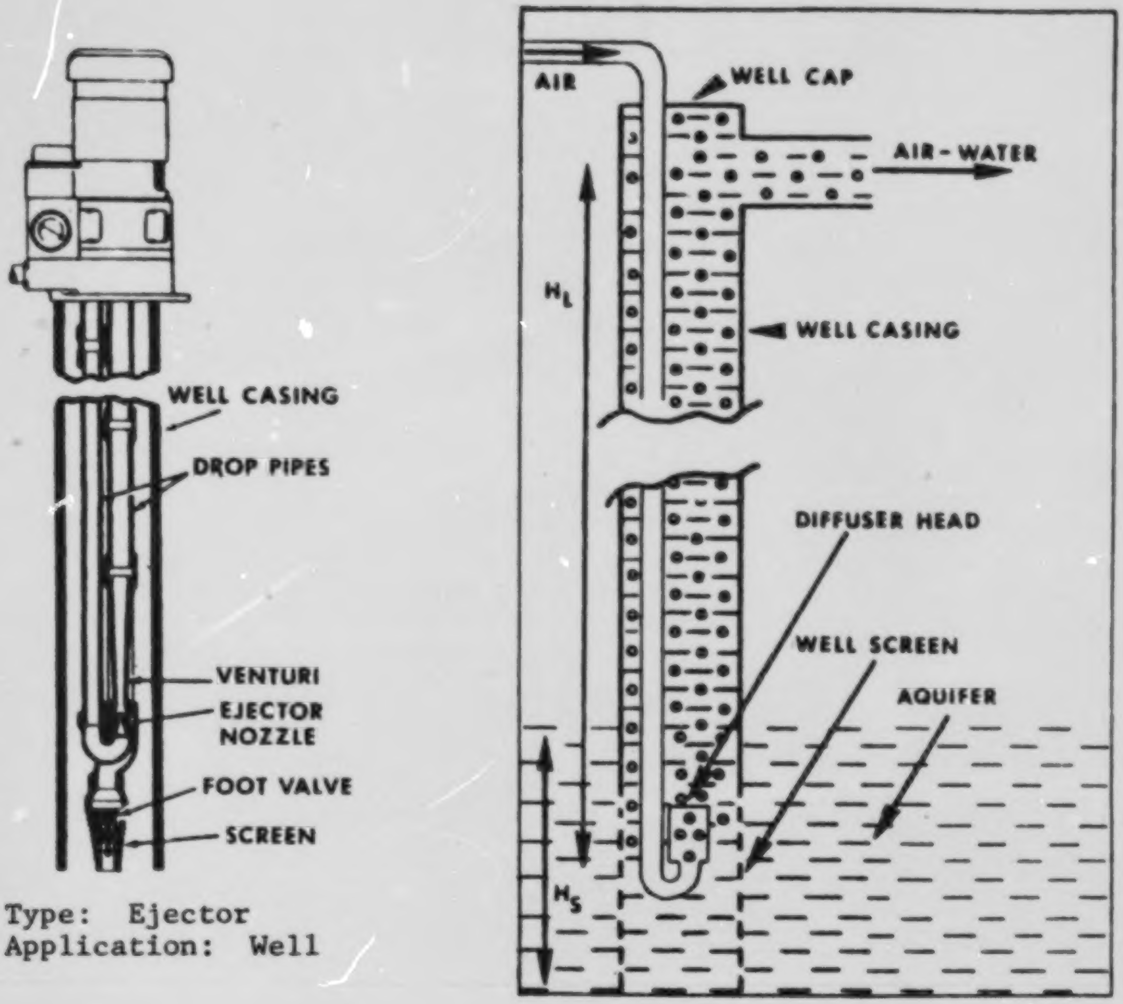
The other main use of pumps in the water supply system is in the treatment plant as chemical feed pumps. These are smaller pumps which will be handling fluids other than water. They are specialty items utilizing different techniques (such as the peristaltic pump) and sometimes requiring the use of non-reactive materials. Typically, a chemical feed pump system is employed to inject exact amounts of a chemical additive into a water source or supply line or as a functioning component of a treatment process. It may do so either at a constant rate or in proportion to the water flow rate. System complexity ranges from that of a simple pump, chemical supply tank with connecting fittings and tubing to sophisticated component sensors and amplifiers, flow measuring equipment, automatic electronic controls, etc.

The following Figures 8.3 - 8.5 are schematic drawings of the six major types of pumps that are typically used in the water treatment systems. Also shown is the typical application of the pump.

Finally, there are some general features used to describe the type of pump:

A single-stage pump has only one impeller.

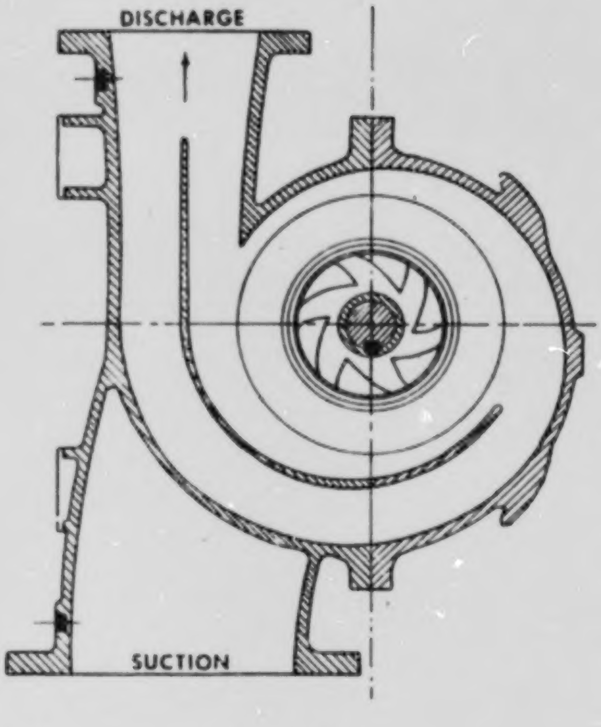
A multistage pump has two or more impellers arranged so that the discharge from one enters the eye of the next impeller.


WELL CASING
DROP PIPES
VENTURI
EJECTOR NOZZLE
FOOT VALVE
SCREEN
AIR
WELL CAP
AIR - WATER
H_L
WELL CASING
DIFFUSER HEAD
WELL SCREEN
AQUIFER
H_S

Type: Ejector
Application: Well

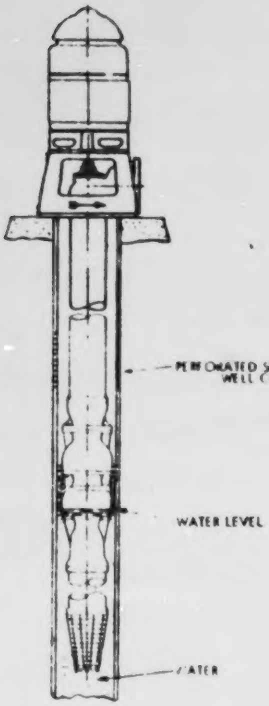
Type: Air Lift
Application: Deep Well

Figure 8.3 Schematics of Ejector and Airlift Pumps

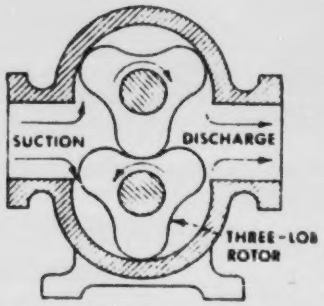

DISCHARGE
SUCTION

Type: Centrifugal
Application: Low Head, High Head
Well, Treatment,
Distribution, Booster

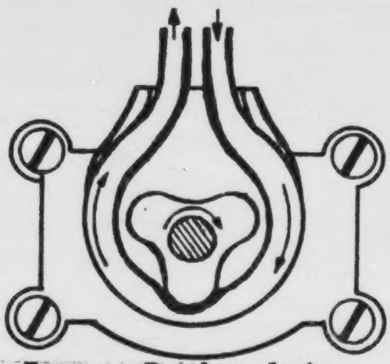
Figure 8.4 Schematic of Centrifugal Pump.


PERFORATED SECTION OF THE WELL CASING
WATER LEVEL
WATER

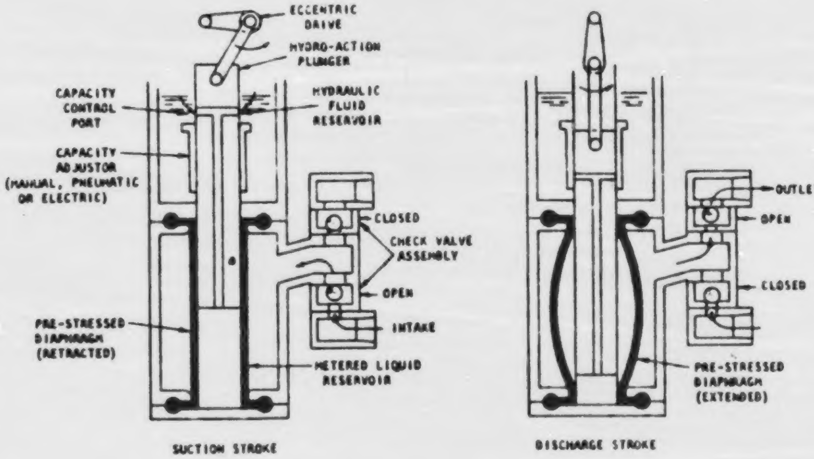
Type: Vertical Turbine
Application: Well, Booster


SUCTION
DISCHARGE
THREE-LOB ROTOR

Type: Rotary
Displacement
Application: Low Head,
Chemical Feed



Type: Peristaltic
Application: Chemical Feed


ECCENTRIC DRIVE
HYDRO-ACTION PLUNGER
CAPACITY CONTROL PORT
HYDRAULIC FLUID RESERVOIR
CAPACITY ADJUSTOR (MANUAL, PNEUMATIC OR ELECTRIC)
CLOSED
CHECK VALVE ASSEMBLY
OPEN
INTAKE
PRE-STRESSED DIAPHRAGM (RETRACTED)
METERED LIQUID RESERVOIR
SUCTION STROKE
OUTLET
OPEN
CLOSED
PRE-STRESSED DIAPHRAGM (EXTENDED)
DISCHARGE STROKE

Type: Reciprocating Displacement
Application: Low Head, High Head, Chemical Feed,
Sludge

Figure 8.5 Schematic of Vertical Turbine, Rotary Displacement, Peristaltic and Reciprocating Displacement Pumps.

A deep-well turbine pump has several impellers on a vertical shaft.

A submersible pump is one in which the pump and electric motor are placed below the water surface.

Pump Performance

Pump performance is described by a variety of characteristics.

(1) Capacity is the rate of pumping expressed normally in gallons per minute.

(2) Brake horsepower (bhp) is the actual horsepower delivered to the pump shaft.

(3) Hydraulic horsepower (whp) is the liquid horsepower delivered by the pump.

(4) Pump efficiency is the ratio of whp to bhp.

Pump performance is shown graphically on a characteristic curve typically showing total dynamic head, brake horsepower, efficiency and net positive suction head plotted versus capacity range (Figure 8.6). Usually a manufacturer produces a composite curve which depicts pump performance at a given speed with various impeller diameters. Horsepower, efficiency and required NPSH are superimposed over the head curves. These curves are only approximations based upon one or two measured points in the range of maximum efficiency. Tests can be done at the factory and a certified performance curve produced.

The characteristic curve indicates the performance of a particular pump. For the pump characterized by Figure 8.3, as flow increases through the capacity range:

Net Positive Suction Head Increases

Total Dynamic Head Decreases

Efficiency Increases Sharply to a Peak and Then Slowly Decreases

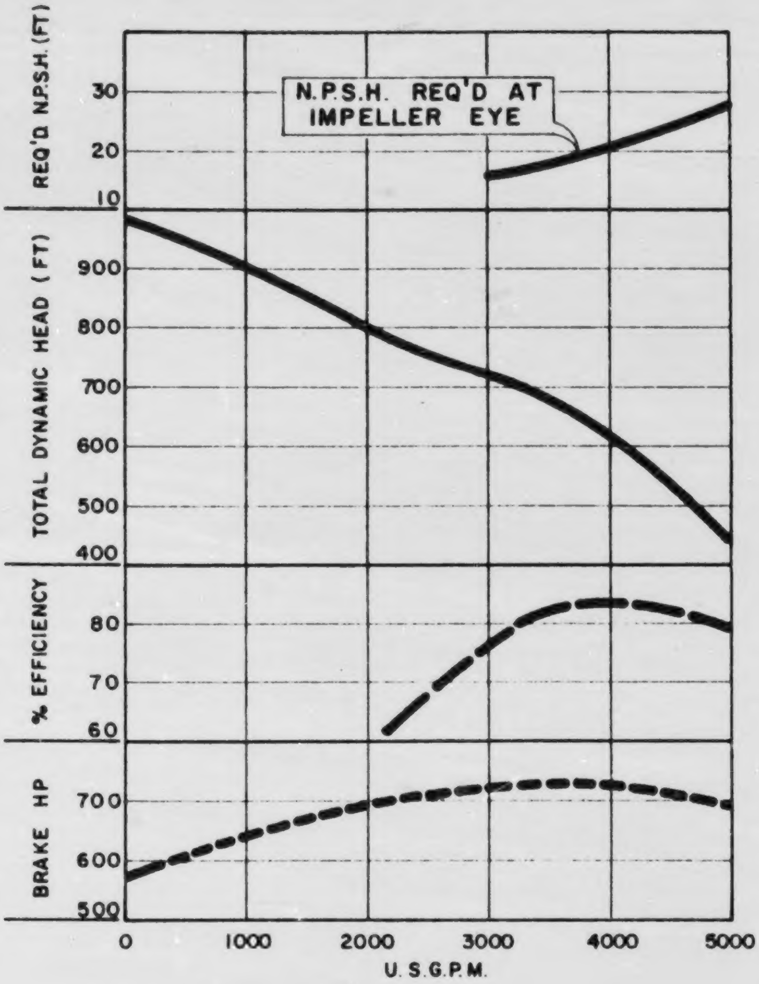


Figure 8.6 Typical Vertical Turbine Characteristic Curves. (Adapted from Walker, Rodger. 1972. Pump Selection A Consulting Engineer's Manual. Ann Arbor Science Publishers Inc., Ann Arbor, Michigan.)

Brake Horsepower Increases Slowly to a Peak and Then Slowly Decreases.

The original installation matched a particular pump to the actual conditions (at the time of installation) of NPSH, TDH and desired flow rate. For instance, given the system conditions of 25 feet of NPSH, 610 feet of TDH and a desired flow rate of 4,000 gallons per minute the pump characterized by Figure 8.3 would operate at maximum efficiency of 84% and require a 725 horsepower motor. If however, any one of the system conditions is changed, a different pump is needed. An increase in the desired flow rate to 5,000 gpm would require a pump capable of overcoming the system TDH of 610 feet whereas the pump of Figure 8.3, at 5,000 gpm, develops only 440 feet of TDH. If, on the other hand, the system TDH was to increase due to pipeline aging or system changes, the flow rate will drop. As an example, if TDH increased from 610 feet to 710 feet, note that not only will flow rate drop from 4,000 gpm to 3,000 gpm but pump efficiency will likewise decrease to about 76% while brake horsepower remains essentially the same. Consequently a 16% increase in TDH resulted in a 25% decrease in flow rate accompanied by an efficiency drop from 84% to 76%. The evaluator needs to be conscious of changes in the structures of the system and sensitive to the problem of pipeline aging in order to analyze pump performance. These may affect the ability of the system to maintain sufficient flow or reserve supplies.

Evaluation of Pumps

Whatever the application, each pump should be evaluated for proper installation, operation and maintenance (See Table 8.1). The evaluator must consider the present and future demands on the pump and relate them to the capacity. This holds true for both prime mover as well as chemical feed pumps. The demand and useage should relate to peak conditions as well as the more normal operation. As part of this evaluation, the relative importance of the pump to the water supply system should be considered. The need for pumping back-up on an auxillary water supply capable of producing only 10 percent of the system needs is quite different from the need for back up on a"heart of the system" pump on the prime source of supply.

The ability of the pump to provide continuous service is critical. The evaluator must be concerned with evidence of proper maintenance, alternate power sources, and inspection procedures. Many manufacturers have manuals on the inspection and maintenance of pumps. Your instructor may be able to supply you with samples from his own collection.

Lastly, the evaluator should be concerned about what affects the pump may have on water quality. There is, of course, the potential for the introduction of contamination at the pumping operation.

TABLE 8.1 Guidelines for Evaluating Public Water Supplies

Function: Collection, Treatment, Distribution

Subfunction: Pumping

Objective: To move liquids or impart energy to liquids.

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Pump Description 1. HP 2. TDH 3. Rated Capacity 4. Aquisition Date 5. Pump Curves 6. Type of Pump	Move liquid or impart energy to liquid		Adequacy	1. Present Capacity vs Demand 2. Pumpage 3. Use Pattern 4. Demand Variations	
			Continuous Service	1. Maintenance records 2. Standby Power and Check Procedures 3. Maintenance Checks a. Lube sched. b. Alignment c. Leveling d. Bearing Insp.	

TABLE 8.1 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: Collection, Treatment, Distribution

Subfunction: Pumping

Objective: To move liquids or impart energy to liquids

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
				e. Shaft Insp. f. Bowl Insp. g. Bearing 4. Power vs Pumpage 5. Rated Cap. vs Present Capacity 6. Stand-by Pump	
			Protection	1. Priming Means 2. Lubrication 3. Cross Connection	

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 9

RAW WATER QUALITY AND TREATMENT

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

RAW WATER QUALITY AND TREATMENT

PURPOSE:

The purpose of this module is to present the basic issues involved in evaluating the "match" between raw water quality and treatment.

OBJECTIVES:

(1) The student will be able to identify water quality regulations.

(2) The student will be able to relate water quality considered unsatisfactory with treatment plans to improve quality.

(3) The student will be able to list specific issues to be considered in his evaluation.

CONTENT:

Introduction
Interim Primary Drinking Water Regulations and Proposed Secondary Regulations
Appropriate Treatment
Evaluation Issues

OTHER RELEVANT MODULES:

Module No. 5. Ground Water
Module No. 6. Surface Water
Module No. 10. Treatment Processes

Introduction

The objectives of the Safe Drinking Water Act are:

(1) to establish new standards which will provide for safe drinking water supplies,

(2) to authorize the Environmental Protection Agency to establish national drinking water regulations,

(3) to provide a mechanism for the individual state to assume responsibility for enforcing the regulations, and

(4) to permit states to strengthen their public water supply supervision programs.

Among the provisions of the SDWA is the requirement for EPA to establish primary regulations for the protection of public health, and secondary regulations (guidelines) relating to the taste, odor and appearance of water (i.e. aesthetics).

A state can qualify for primary enforcement responsibility if it meets the following conditions:

- It adopts and implements adequate surveillance and enforcement procedures,
- It provides variances and exemptions that meet Federal requirements,
- It provides an adequate plan for supplying safe drinking water under emergency circumstances,
- It keeps records and provides reports keeping EPA fully informed of its activities.

Whenever a public water system in a state with primary enforcement authority does not comply with a primary regulation or a schedule imposed with a variance or exemption, EPA will notify the state and will provide advice or technical assistance to bring about compliance. In the case of continued non-compliance, Federal action may be taken. In a state without primary enforcement authority, EPA may take direct civil action.

The secondary regulations are guidelines only. However, states may adopt them for enforcement if they wish.

Interim Primary Drinking Water Regulations and Proposed Secondary Regulations

The EPA issued interim primary drinking water regulations on December 24, 1975 in the Federal Register. These regulations define maximum permissible concentrations of contaminants in water which is delivered to the free flowing outlet of the ultimate user of a public water supply.

Subpart B—Maximum Contaminant Levels

§ 141.11 Maximum contaminant levels for inorganic chemicals.

(a) The maximum contaminant level for nitrate is applicable to both community water systems and non-community water systems. The levels for the other inorganic chemicals apply only to community water systems. Compliance with maximum contaminant levels for inorganic chemicals is calculated pursuant to § 141.23.

(b) The following are the maximum contaminant levels for inorganic chemicals other than fluoride:

Contaminant	*Level, milligrams per liter*
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.
Selenium	0.01
Silver	0.05

(c) When the annual average of the maximum daily air temperatures for the location in which the community water system is situated is the following, the maximum contaminant levels for fluoride are:

Temperature Degrees Fahrenheit	Degrees Celsius	Level, milligrams per liter
53.7 and below	12.0 and below	2.4
53.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.3 to 90.5	26.3 to 32.5	1.4

§ 141.12 Maximum contaminant levels for organic chemicals.

The following are the maximum contaminant levels for organic chemicals. They apply only to community water systems. Compliance with maximum contaminant levels for organic chemicals is calculated pursuant to § 141.24.

	Level, milligrams per liter
(a) Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10, 10-hexachloro-6,7-epoxy-1,4, 4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8 - dimethano naphthalene).	0.0002
Lindane (1,2,3,4,5,6-hexachlorocyclohexane, gamma isomer).	0.004
Methoxychlor (1,1,1-Trichloro-2, 2 - bis [p-methoxyphenyl] ethane).	0.1
Toxaphene ($C_{10}H_{10}Cl_8$-Technical chlorinated camphene, 67-69 percent chlorine).	0.005
(b) Chlorophenoxys:	
2,4 - D, (2,4-Dichlorophenoxyacetic acid).	0.1
2,4,5-TP Silvex (2,4,5-Trichlorophenoxypropionic acid).	0.01

§ 141.13 Maximum contaminant levels for turbidity.

The maximum contaminant levels for turbidity are applicable to both community water systems and non-community water systems using surface water sources in whole or in part. The maximum contaminant levels for turbidity in drinking water, measured at a representative entry point(s) to the distribution system, are:

(a) One turbidity unit (TU), as determined by a monthly average pursuant to § 141.22, except that five or fewer turbidity units may be allowed if the supplier of water can demonstrate to the State that the higher turbidity does not do any of the following:

(1) Interfere with disinfection;

(2) Prevent maintenance of an effective disinfectant agent throughout the distribution system; or

(3) Interfere with microbiological determinations.

(b) Five turbidity units based on an average for two consecutive days pursuant to § 141.22.

§ 141.14 Maximum microbiological contaminant levels.

The maximum contaminant levels for coliform bacteria, applicable to community water systems and non-community water systems, are as follows:

(a) When the membrane filter technique pursuant to § 141.21(a) is used, the number of coliform bacteria shall not exceed any of the following:

(1) One per 100 milliliters as the arithmetic mean of all samples examined per month pursuant to § 141.21 (b) or (c);

(2) Four per 100 milliliters in more than one sample when less than 20 are examined per month; or

(3) Four per 100 milliliters in more than five percent of the samples when 20 or more are examined per month.

(b)(1) When the fermentation tube method and 10 milliliter standard portions pursuant to § 141.21(a) are used, coliform bacteria shall not be present in any of the following:

(i) more than 10 percent of the portions in any month pursuant to § 141.21 (b) or (c);

(ii) three or more portions in more than one sample when less than 20 samples are examined per month; or

(iii) three or more portions in more than five percent of the samples when 20 or more samples are examined per month.

(2) When the fermentation tube method and 100 milliliter standard portions pursuant to § 141.21(a) are used, coliform bacteria shall not be present in any of the following:

(i) more than 60 percent of the portions in any month pursuant to § 141.21 (b) or (c);

(ii) five portions in more than one sample when less than five samples are examined per month; or

(iii) five portions in more than 20 percent of the samples when five or more samples are examined per month.

(c) For community or non-community systems that are required to sample at a rate of less than 4 per month, compliance with paragraphs (a), (b)(1), or (b)(2) of this section shall be based upon sampling during a 3 month period, except that, at the discretion of the State, compliance may be based upon sampling during a one-month period.

Regulations for radioactivity
were issued on July 9, 1976

§ 141.15 Maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity in community water systems.

The following are the maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity:

(a) Combined radium-226 and radium-228—5 pCi/1.

(b) Gross alpha particle activity (including radium-226 but excluding radon and uranium)—15 pCi/1.

§ 141.16 Maximum contaminant levels for beta particle and photon radioactivity from man-made radionuclides in community water systems.

(a) The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/year.

(b) Except for the radionuclides listed in Table A, the concentration of man-made radionuclides causing 4 mrem total body or organ dose equivalents shall be calculated on the basis of a 2 liter per day drinking water intake using the 168 hour data listed in "*Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure,*" NBS Handbook 69 as amended August 1963, U.S. Department of Commerce. If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 millirem/year.

TABLE A.—*Average annual concentrations assumed to produce a total body or organ dose of 4 mrem/yr*

Radionuclide	Critical organ	pCi per liter
Tritium	Total body	20,000
Strontium-90	Bone marrow	8

In addition to the MCLs analytical and monitoring requirements for each parameter are also defined in the above regulations.

It is proposed that the secondary regulations contain the following:

Constituent	Recommended Maximum Level
Odor	3 T.O.N.*
Manganese	0.05 MG/L
Iron	0.3 MG/L
Foaming Agents (MBAS)	0.5 MG/L
Copper	1.0 MG/L
Color	15 color units
Chloride	250 MG/L
Sulfate	250 MG/L
Zinc	5 MG/L
Hydrogen Sulfide	0.05 MG/L
Corrosion	Non-corrosive

*Threshold odor number

Appropriate Treatment

The EPA has prepared a series of documents (Treatment Technique Documents, 1976) which discuss the treatment methods that have the highest potential for achieving water quality that meets the promulgated primary standards. These treatment methods are as follows:

Contaminant	Most Effective Method
Arsenic III	Ferric Sulfate Coagulation, pH 6-8 Alum Coagulation, pH 6-7 Excess Lime Softening Oxidation Prior to Treatment Required
Arsenic V	Ferric Sulfate Coagulation, pH 6-8 Alum Coagulation, pH 6-7 Excess Lime Softening
Barium	Lime Softening, pH 10-11 Ion Exchange

Contaminant	Most Effective Methods
Cadmium	Ferric Sulfate Coagulation, above pH 8 Lime Softening Excess Lime Softening
Chromium III	Ferric Sulfate Coagulation, pH 6-9 Alum Coagulation, pH 7-9 Excess Lime Softening
Chromium VI	Ferrous Sulfate Coagulation, pH 7-9.5
Fluoride	Ion Exchange with Activated Alumina or Bone Char Media
Lead	Ferric Sulfate Coagulation, pH 6-9 Alum Coagulation, pH 6-9 Lime Softening Excess Lime Softening
Mercury, Inorganic	Ferric Sulfate Coagulation, pH 7-8
Mercury, Organic	Granular Activated Carbon
Nitrate	Ion Exchange
Selenium IV	Ferric Sulfate Coagulation, pH 6-7 Ion Exchange Reverse Osmosis
Selenium VI	Ion Exchange Reverse Osmosis
Silver	Ferric Sulfate Coagulation, pH 7-9 Alum Coagulation, pH 6-8 Lime Softening Excess Lime Softening
Turbidity	Granular Media Filtration Diatomaceous Earth Filtration
Radium	Lime Softening, pH > 10 Ion Exchange Reverse Osmosis
Coliform Bacteria	Chlorination Ozonation

It is important to point out that many of these methods require the careful manipulation and control of one or more operational parameters. These include temperature, time, pH, turbidity and a variety of interfering inorganic and organic materials. For example, conventional coagulation treatment and lime softening are usually dependent on the pH of treated water, the type and dose of the coagulant, and the initial concentration of the contaminant. Of these variables, pH appears to be most important. This is because the solubility limits for metal hydroxides, carbonates and other chemical species are normally pH dependent. Similarly, there is a variety of factors that can influence the operation of granular media filters, including the proper conditioning of the water before filtration, and through backwashing of media at the end of each run. Variables affecting floc strength and completeness of flocculation are rapid mix time and energy, flocculation time and energy, and inorganic chemicals and/or polymers and doses used.

Because of the complexity of interrelationships between variables in any treatment process, the evaluator should consult EPA's Technique Documents and other relevant literature on individual treatment methods. It is vitally important that the evaluator consider not only whether an appropriate method is being utilized, but also whether that method is being correctly utilized.

Evaluation Issues

The basic issues involved in the evaluation of raw water quality with respect to treatment are (1) does the finished water quality meet the appropriate standards or guidelines for all parameters, and (2) are the treatment methods employed utilized in such a way that standards and guidelines are met even when there are fluctuations in raw water quality.

The most important source of information on these issues are the plant records, including records of raw and finished water analyses and records of operational laboratory testing. The evaluator should ensure that all parameters included in the primary regulations are in fact monitored, that they are being monitored and analyzed according to protocols established by the regulations, and that analytic results conform to the desired standards.

TABLE 9.1 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Raw Water Quality vs Treatment

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Water Quality - Describe Treatment Provided in Brief. List Raw Water Quality Analysis Results	Water Safe to Drink and Palatable		Adequacy	1. Raw water quality vs finished water quality vs appropriate standard or guideline for all parameters. 2. Variability of raw water quality.	

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 10

TREATMENT PROCESSES

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

TREATMENT PROCESSES

PURPOSE:
The purpose of this module is to familiarize the student with the unit processes as they relate to specific treatment processes, and to introduce specific evaluation issues.

OBJECTIVES:

(1) The student will be able to distinguish between the terms unit process, treatment objective and treatment processes.
(2) The student will be able to list common treatment processes and associate treatment objectives with each process.
(3) The student will be able to identify the various unit processes involved in specific treatment processes.
(4) The student will be able to identify some basic evaluation issues pertinent to each treatment process.

CONTENT:

Introduction
Aeration
Evaluation Issues for Aeration
Taste and Odor Control
Evaluation Issues for Taste and Odor Control
Water Stabilization
Evaluation Issues for Water Stabilization
Fluoridation
Evaluation Issues for Fluoridation
Evaluation Issues for Iron and Manganese Removal
Coagulation - Flocculation
Evaluation Issues for Coagulation
Sedimentation
Evaluation Issues for Sedimentation
Filtration
Evaluation Issues for Filtration
Disinfection
Evaluation Issues for Disinfection
Softening
Evaluation Issues for Softening

OTHER RELEVANT MODULES:

Module No. 9.	Raw Water Quality and Treatment
Module No. 11.	Chemical Feed and Storage
Module No. 13.	Operational Laboratory Testing

Introduction

"Treatment objective" and "unit process" are two important terms in treatment processes. The treatment objective is the goal of the treatment process to produce water meeting certain water quality standards and guidelines. Unit processes are those processes that introduce specific materials into water and/or remove specific materials from water, and/or transform materials already in water. A treatment process may utilize one or more unit processes to achieve a treatment objective. Figure 10.1 relates these terms.

Unit processes include:

(1) Gas Transfer: the release of gases from water or the dissolving of gases by water.

(2) Ion Transfer: the use of chemical coagulation, chemical precipitation, ion exchange, and adsorption where,

- a. chemical coagulation is the process of adding floc-forming chemicals to enmesh or combine with suspended and colloidal solids to form rapidly settling and readily filterable aggregates,
- b. chemical precipitation is the addition of soluble chemicals which react with soluble chemicals already in the water to form precipitates,
- c. ion exchange is the exchange of specific ions in water for complementary ions which are part of the complex of a solid exchange medium,
- d. adsorption is the removal of ions and molecules from solution by attraction to the interface of an adsorbent material.

(3) Solute Stabilization: the conversion of an objectionable solute to an unobjectionable form without removal.

(4) Solids Transfer: the removal of solids through use of the specific gravity of the solid as related to the specific gravity of water. Methods are straining, sedimentation, flotation and screening:

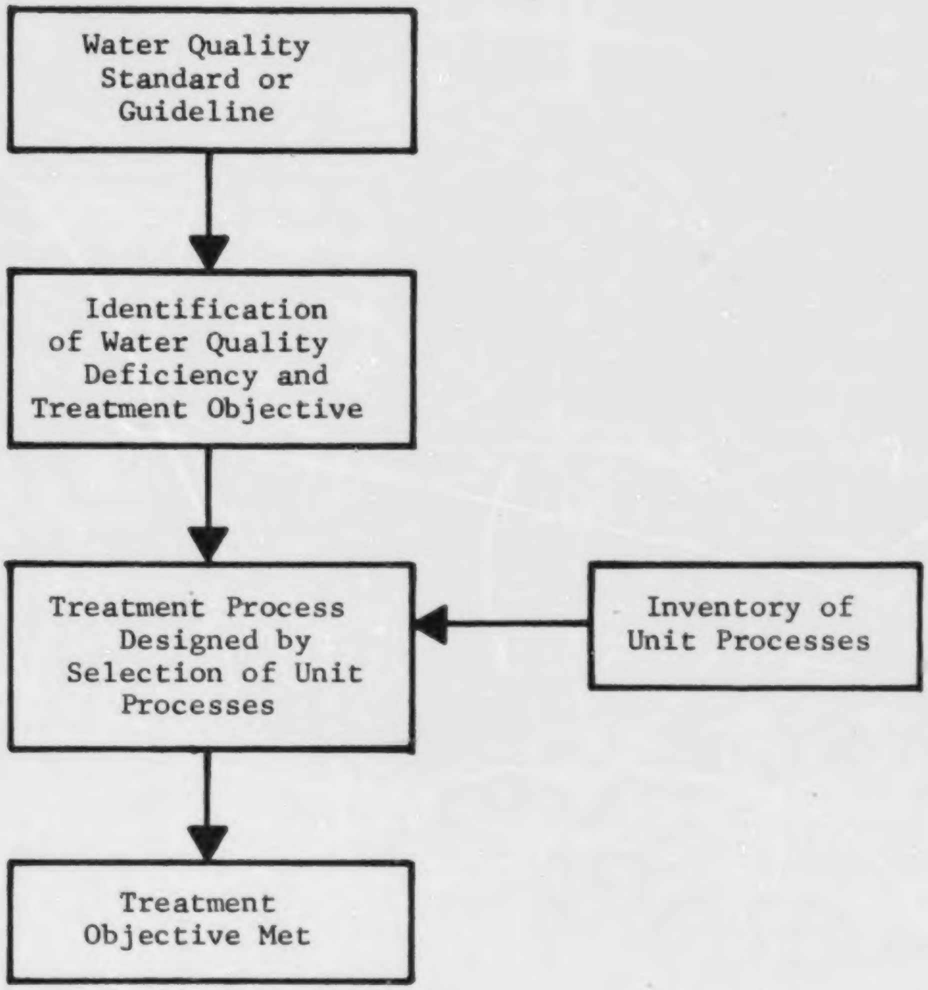

Water Quality Standard or Guideline
Identification of Water Quality Deficiency and Treatment Objective
Treatment Process Designed by Selection of Unit Processes
Inventory of Unit Processes
Treatment Objective Met

FIGURE 10.1 Relationship of Treatment Objectives and Processes.

a. straining is solids removal through the use of screens or racks,

b. sedimentation is solids removal by slowing flow to permit suspended particles to settle by gravity to the bottom of the holding tanks,

c. flotation is solids removal by slowing flow to permit substances lighter than water to rise to the surface where they are skimmed off,

d. filtration is solids removal by passing the water through sand, coal or other granular materials from which the solids are later removed.

(5) Miscellaneous Unit Processes include:

- Disinfection of water by chemicals that kill potentially infectious organisms,
- Copper sulfating to control algae, and
- Fluoridation to reduce dental caries.

The most common treatment processes which utilize various unit processes in water supply treatment are:

(1) Aeration

(2) Taste and Odor Control

(3) Water Stabilization

(4) Fluoridation

(5) Iron and Manganese Removal

(6) Coagulation - Flocculation

(7) Sedimentation

(8) Filtration

(9) Disinfection

(10) Softening

In the following parts each of these treatment processes is discussed and evaluation issues examined.

Aeration

Aeration is utilized either for the removal of gases and other volatile substances from water or for their addition to water, or both at the same time. Typical objectives of aeration include:

(1) reduction of substances producing tastes and odors

(2) reduction of substances that increase the corrosive action of water (e.g. carbon dioxide and hydrogen sulfide)

(3) reduction of substances that react or interfere with chemicals used in the treatment of water (e.g. carbon dioxide which interferes with softening and iron removal processes)

(4) reduction of miscellaneous gases (e.g. methane)

(5) increase in atmospheric gases, particularly oxygen, which is useful in the improvement of taste and odor, for the oxidation of iron, manganese, hydrogen sulfide, and other organic matter

(6) increase carbon dioxide in order to neutralize causticity after softening with excess lime, and to lower the pH for the purpose of increasing the volatility of hydrogen sulfide.

The most important functions of aeration are the removal of carbon dioxide from water prior to lime-soda softening, and the addition of oxygen for the removal of iron and manganese.

The interchange of substances from water to air or from air to water takes place at the air-water surface. The rate at which the interchange occurs is the result of the relative concentration of the substance at this surface and the rapidity with which new surfaces are formed and exposed. Thus the ratio of surface area to the volume of water, and the time factor are important factors in the design of an aerator.

Aeration equipment used in present practice employs one of two methods to control time and the ratio of surface area to the volume of water. One method exposes water films to the air (i.e., the "waterfall type"), and the other introduces air in the form of small bubbles in the water (i.e., the "diffused air type").

There are several kinds of waterfall (or gravity) aerators that are in common use in water purification plants (Figure 10.2):

(1) Cascades, in which the available fall is subdivided into a series of steps

(2) Inclined planes, usually studded with riffle plates set into the planes in herringbone fashion and breaking up the sheet of water that would otherwise form

(3) Vertical stacks through which droplets fall and updrafts of air ascend in countercurrent flow

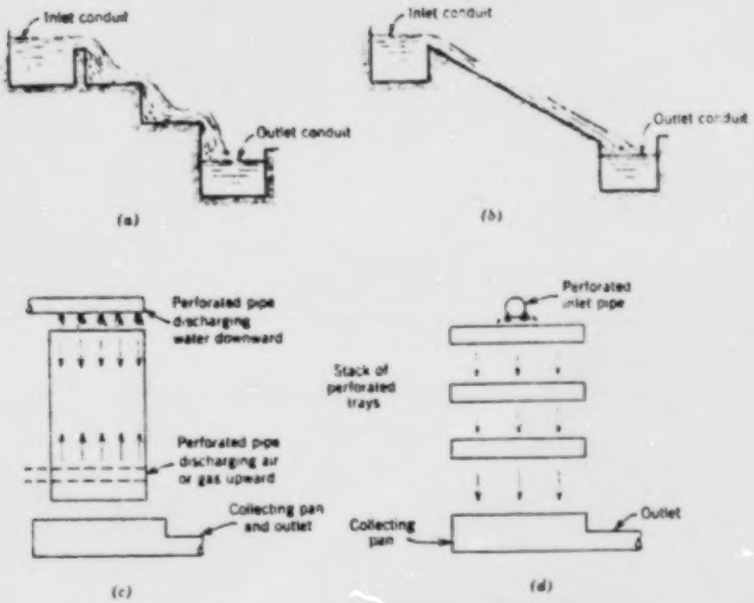
(4) Stacks of Perforated Pans (trays), often filled with contact media such as coke or stone, the water dropping freely from tray to tray and trickling over the surfaces of the contact media.

Air diffusers (or diffused air or injection aerators) bubble compressed air into water through orifices or nozzles in air piping, diffuser plates or tubes. Ascending bubbles acquire smaller terminal velocities than would drops falling freely in air through the same distance. This increases the exposure time of air bubbles but reduces turbulence at the bubble interface. Spiral or cross-current flow can lengthen the path of travel of both air and water. This can be done by injecting air along one side of the tank. (See Figure 10.2).

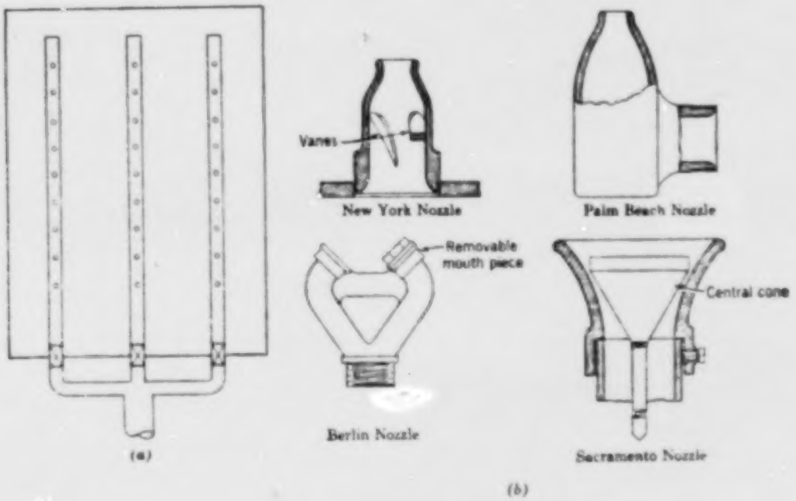
Evaluation Issues for Aeration

It is important that aeration devices be properly protected from airborne contamination. This is typically accomplished with screening that prevents birds from having access to the structure.

Continuous service of aerator-devices depends upon adequate housing (to prevent freezing), and adequate maintenance. Housing is very important for waterfall type aerators. Air-diffusers do not usually present problems during winter operation, and thus the need for housing for this type of structure is generally eliminated. Maintenance for all aerators should include periodic chlorination for the prevention of slime growth,and repair of corroded parts. The evaluator should consult appropriate plant records to ensure that such corrective and preventive maintenance is accomplished.


Inlet conduit
Outlet conduit
(a)
Inlet conduit
Outlet conduit
(b)
Perforated pipe discharging water downward
Perforated pipe discharging air or gas upward
Collecting pan and outlet
(c)
Perforated inlet pipe
Stack of perforated trays
Collecting pan
Outlet
(d)

Gravity aerators. (a) Cascade; (b) inclined apron possibly studded with riffle plates; (c) tower with countercurrent flow of air (gas) and water; (d) stack of perforated pans possible containing contact media.


Vanes
New York Nozzle
Palm Beach Nozzle
Removable mouth piece
Central cone
Berlin Nozzle
Sacramento Nozzle
(a)
(b)

Spray aerator and nozzles. (a) Nozzled aerator; (b) aerator nozzles.

Figure 10.2 Schematics of Gravity and Spray Aerators. (Adapted from Fair, G.M., Geyer, J.C., Okun, D.A. 1968. Water and Wastewater Engineering, Volume 2. John Wiley & Sons, Inc., New York, New York.)

The adequacy of aeration may be evaluated in terms of the concentrations of iron and manganese in water after aeration, and by noting consumer complaints of odors, including odors typical of hydrogen sulfide and methane. (See Table 10.1).

Taste and Odor Control

Although taste and odor cannot be directly correlated with the safety of the water supply, its presence can cause consumers to seek other supplies that may be less safe. The incomplete removal of taste- and odor-bearing substances suggests to the layman the possibility of potentially toxic substances being present.

Tastes and odors can result from the presence of inorganic or organic materials, or biological action. While inorganic compounds, such as metal ions in concentrations of ppm, impart taste to water, the main sources of odor are organic materials. These materials can cause persistent difficulties when present in even trace amounts of only a few parts per billion (ppb). Examples of important taste and odor causing materials and detectable concentrations are:

Formaldehyde	- 50,000 ppb
Picolines	- 500-1000 ppb
Phenolics	- 250-4000 ppb
Xylenes	- 300-1000 ppb
Refinery Hydrocarbons	- 25-50 ppb
Petrochemical Waste	- 15-100 ppb
Phenylether	- 13 ppb
Chlorinated Phenolics	- 1-100 ppb

Algal growth is the most common biological source of taste and odor in water. The actual source of algae odors are the organic compounds resulting from the metabolic activity of algae. The organic odoriferous material is for the most part retained within the cells of the algae until their death or disintegration.

The possibility exists that taste and odor may develop in the distribution system. This is sometimes caused by biological

TABLE 10.1 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Aerators

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Aerator Description 1. Coke trays 2. Forced draft 3. Cascades 4. Tray	Oxidation of iron and manganese to insoluble states.		Protection	1. Screening to prevent birds from lighting on the structure.	
	Removal of dissolved gases such as carbon dioxide, hydrogen sulfide and organic gases		Continuous Service	1. Housing to prevent freezing 2. Maintenance records (a) chlorination to prevent slime growth (b) repair of corroded parts	

TABLE 10.1 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Treatment

Subfunction: Aerators

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Adequacy	1. Fe and/or Mn water quality 2. Consumer complaints on H_2S or CH_4	

growth or by the delayed reaction of chlorine, which is routinely used as a disinfectant, with organic compounds present in the finished water.

One of the most commonly used methods for organics removal is activated carbon. There are two types of activated carbon used in water treatment: powdered and granular. Powdered activated carbon is primarily used in routine water treatment practices. It is applied as a suspension or slurry prior to filtration. Granular activated carbon is used in the form of carbon beds. Such beds may take the form of capping of rapid sand filters or may be special beds placed after the conventional filtration system.

The optimum point of application of the powdered carbon is dependent on a number of interrelated factors that must be properly evaluated in terms of the overall water quality objective. Sufficient contact time between the carbon and the taste and odor compounds is necessary to ensure maximum adsorption. The need for adequate dispersion of the carbon makes the rapid mix system for other chemicals a logical point for carbon addition. The carbon is always added at a point before filtration. Economy of use may indicate the influent to the filters as the "best" point for application.

Raising the pH by the addition of softening chemicals makes the adsorption of odorous organic compounds less efficient. More carbon is usually required to produce a palatable water when chlorine is applied before carbon than when chlorine is applied after carbon.

In addition to the point of application, the amount of carbon needed depends on the source and intensity of the taste and odor and on the type of carbon. The dosage of carbon needed is usually determined empirically by checking the product water for taste and odor.

Granular activated carbon beds have limited use for application in those supplies having severe taste and odor problems. References on such use include: Dostal, K.A., R.C. Pierson, D.G. Hager, and G.G. Robeck, 1965. Carbon Bed Design Criteria Study at Mitro, W. Va. J. AWWA, 57:663(1965). Hager, D.G. and M.E. Flentje, 1965. Removal of Organic Contaminants by Granular Carbon Filtration. Presented at the 85th Annual AWWA Conference, Portland, Oregon, July 1965.

Other treatment processes that may be employed for taste and odor control include the oxidation of taste and odor causing materials by aeration, chlorination, ozonation, chlorine dioxide, and potassium permanganate.

Aeration is seldom if ever used as the sole source of odor removal, but does decrease the amounts of materials required to remove remaining odors. Both waterfall and diffused-air aerators may be employed. Chlorination, used primarily for disinfection purposes, is probably the most popular of the oxidation methods used for taste and odor control. In addition to being a strong oxidizing agent, free chlorine also controls the growth of odor-causing algae and microorganisms, thus removing additional taste and odor bearing substances. Such variables as pH, temperature, quantity, and type of organic matter in the water influent have a marked effect on the efficiency of removal of odorous materials and the detention times required to ensure palatable water. Ozone treatment is generally most effective in waters having high threshhold odors, and is of less value when odors are moderate to low. Typical dosages of ozone are 8-50 lb. of ozone per million gallons of water. Chlorine dioxide oxidizes odorous substances at a faster rate than does chlorine, and has been demonstrated to be effective in the destruction of a variety of odorous substances, including chlorophenols. Finally, potassium permanganate is increasingly used as an effective oxidizing agent for the destruction of tastes and odors. Although there are various points in the treatment system where permanganate may be added, it is normally applied in pretreatment at the rapid mix. It may be added before, during, or after chlorination. However, if organic materials capable of forming odorous chloro derivatives are present in the water, chlorine should not be used before the permanganate is consumed. Normal dosage ranges between 1 - 5 ppm. Effective visual control is possible because of the characteristic pink color of potassium permanganate in water.

Evaluation Issues for Taste and Odor Control

The evaluator should consider three major items pertaining to the effective use of taste and odor control processes - (1) the adequacy of treatment, (2) safety of plant personnel, and (3) protection of the treated supply.

The adequacy of treatment may be evaluated in terms of the complaint records that may indicate periodic or long-term inefficiency in taste and odor treatment. Threshhold odor numbers should also be checked in order to ensure that the proper treatment process has been employed, and that the process is effective. Depending upon the process employed, the evaluator should also ensure that the appropriate chemicals are available in amounts appropriate both to normal and "problem" periods of operation. Evaluation issues important to the adequacy of treatment by means of chemical oxidation and aeration are discussed in other sections of this module.

Important safety issues include the type and condition of dust control equipment used in conjunction with the handling of chemicals employed in the various taste and odor treatment processes. The evaluator should ensure that this equipment is functioning properly, and that preventive maintenance is conducted. The evaluator should also ensure that protection equipment is available to the operator and that all proper personal equipment is utilized during chemical handling, mixing and application. It is also essential for plant safety that all electrical equipment is separated from areas in which powders are stored.

These and additional evaluation issues are summarized in Table 10.2 .

Water Stabilization

Water stabilization is the treatment of water so as to reduce and control corrosion. The importance of corrosion control lies in several effects of corrosive water, including (1) significant losses in the hydraulic carrying capacity of pipes, fittings, and other system components, (2) possible structural failures, and (3) debased quality of the water transported.

Waters may be classified with respect to their corrosion potential in terms of their mineral content, dissolved oxygen, and pH. Some of these classifications are as follows:

(a) No minerals; dissolved oxygen present: In the absence of minerals, increasing pH decreases corrosion rates by water containing dissolved oxygen.

(b) No minerals; dissolved oxygen absent: In the absence of dissolved oxygen, the pH of "high purity" water

TABLE 10.2 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Taste and Odor Control

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Carbon Addition Storage Feed	Adsorb odorous material See Module 11		Adequacy	1. Complaint records 2. Threshhold odor #s 3. Inventory records vs problem periods	
			Safety	1. Dust control equip. functional 2. Separation of electrical equip. & powder storage 3. Use of individual protection equip.	

TABLE 10.2 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: **Treatment**

Subfunction: **Taste and Odor Control**

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Chemical Oxidation **1. Chlorination** **2. Ozone** **3. Chlorine Dioxide** **4. Potassium Perm.**	**Oxidize T & O matl. to non-odorous matl.**		**Adequacy**	**1. Complaint records** **2. Threshhold odor #s** **3. See Module 10 Section on chlorin.** **4. See Module 13**	
			Safety	**1. See chlor. section and Module 13**	
			Protection	**1. Cross Connection** **2. Pink Water**	
Aeration	**Permit release of volatile gases**	See Module	10 Section on	Aeration	

adjusts itself to about 8.4 and corrosion becomes negligible. However, all natural waters are mineralized to some degree.

(c) Noncarbonate minerals; dissolved oxygen present: In the absence of carbonate minerals increasing concentrations of other minerals (e.g., chloride, sulfate) increase the corrosion rate at all pH values. Increasing temperature accelerates corrosion.

(d) Carbonate minerals (no calcium); dissolved oxygen present: Carbonate minerals indicated by the alkalinity determination for bicarbonates inhibit corrosion. In the absence of calcium, this inhibition is maximum at a pH of 6.5 - 7.0 when alkalinity is more than 5 - 10 times the chloride and sulfate salts, corrosion rates increase.

(e) Minerals; dissolved oxygen absent: In the absence of dissolved oxygen, the types of mineralizations are less important with respect to useful life of mild steel.

(f) Calcium salts; dissolved oxygen present: Stability as indicated by saturation with calcium carbonate is the most widely accepted criterion in classification. However, for uncoated mild steel, a very significant supersaturation must exist to form a visible deposit. Specific limitations may be found in: American Water Works, Association, 1971. Water Quality and Treatment (3rd Edition). McGraw-Hill Book Company.

On the whole, chemical control of corrosion has been more successful with water used for industry than with water used for drinking. With respect to water supply systems, it should also be pointed out that chemical control is a supplement to protective measures (including the use of corrosion-resistent materials) and cannot overcome improper flow conditions, poorly designed distribution systems, defective materials, grossly faulty coatings and underdesign of piping.

Silicate treatment is a popular treatment for corrosion control, particularly on waters with very low hardness, alkalinity and pH less than about 8.4. This treatment involves the use of sodium silicate in one of the various proportions of Na_2O and SiO_2. Its effectiveness is apparently dependent on the adsorption of silica in the hydroxide corrosion products of iron and zinc. Treatment must be relatively continuous; and effectiveness is favored by high velocity and generally lower pH values. Recommended dosages have included 12-16 mg/l of SiO_2 for about a month, followed by the maintenance of a residual of 1 mg/l in remote parts of the distribution system (Gordon Fair, Geyer, J.C. and Okun, D.A., 1968. Water and Wastewater Engineering, John Wiley and Sons, Inc.).

Polyphosphate treatment has also been reported to be effective in reducing corrosion by domestic waters. The effectiveness of polyphosphates is progressively greater at increasing turbulent velocities and at increasing concentrations. Under essentially no conditions are polyphosphates effective in stagnant or nearly stagnant water such as in deadends or service lines. Available data indicate a slight increase in corrosion at 0.5 fps. It should be noted that conditions of 2-5 fps or more or turbulent flow velocities are not experienced continually in all parts of a distribution system, and certainly not in communities where the grid has been designed with 5-10 miles of 4- and 6-inch pipe for a 30,000 gpd consumption.

By far the most applicable and successful condition for prevention of "red water" and tuberculation is the natural occurrence or controlled production of a stable or a supersaturated water with respect to calcium carbonate. There are limitations to this approach, however, including; velocity of flow, and minimum concentrations of calcium and alkalinity.

It is generally concluded that corrosion can be controlled by chemicals only on the basis of careful experimentation. Laboratory tests are not enough. They must be followed up in the field. Flow tests are the most instructive overall measures of the effectiveness of corrosion control in pipelines and distribution systems.

Evaluation Issues for Water Stabilization

As indicated above, depending on influent water quality, velocities in distribution systems, and various other chemical and physical aspects of a water supply system, corrosion control may involve the adjustment of pH, alkalinity and calcium, and may also include the additions of polyphosphate and/or sodium silicate.

The adequacy of such treatment is ultimately determined by the effects of corrosion, and including the need for water heater replacement, fixture staining, line failures, increased pumping costs (over the long term) and pressure losses (long term). The evaluator should review all user complaints in an effort to identify these effects of corrosive waters, and should (where appropriate) visually examine pipes for evidence of corrosion. Laboratory records should also be reviewed for evidence of those operational tests (stability tests) which determine the type and amount of chemical adjustment required. The evaluator should also assure himself that there are no cross connections between stabilized and non-stabilized waters. These issues are summarized in Table 10.3.

Fluoridation

Fluoride in excess of 1.5 mg/l is undesirable and in higher amounts causes mottling of the teeth of children. However, it has been found that a fluoride concentration of about 1.0 mg/l prevents dental caries in children. In many cases such a fluoride concentration has reduced tooth decay by 50 to 65 percent.

A great many communities add fluoride to the water when the water is deficient. Several fluoride compounds are used for water treatment, among these are sodium fluoride, hydrofluosilicic acid, and sodium silicofluoride.

Sodium fluoride is made from the neutralization of hydrofluoric acid with sodium carbonate. It is a white, odorless material available either as a powder or as various size crystals. It solubility is practically constant at 4.0 grams per 100 ml (4% solution) of water at ambient temperatures. Purities range from 90 to 98 percent. The impurities consist of water, free acid or base, sodium silicofluoride, sulfites, and iron.

Sodium silicofluoride is made in an analogous manner from hydrofluosilicic acid. This compound is the most commonly used chemical for fluoridation. The primary attraction is in its low cost. Sodium silicofluoride is also a white, odorless, crystalline powder. The solubility varies between 0.37 grams per 100 ml at 32°F to about 2.5 grams per 100 ml of water at the boiling point. Commercial purities are generally in excess of 98 percent. The

TABLE 10.3 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Water Stabilization

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Chemical Injection Equipment Description 1. Location 2. Chemicals include: a) pH adjustment b) alk.adjustment. c) Ca adjust. d) add polyphosphate e) add sodium silicate 3. Storage 4. Feeders	Prevent water from being corrosive. Prevent excessive deposition of material.		Protection	1. Cross Connections	
			Adequacy	1. Stability tests 2. Raw water qual. vs. chemical used vs. water treated. 3. User complaints 4. Visual exam. of pipe 5. Pressure losses-long term 6. Pumpage cost-long term	

TABLE 10.3 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Water Stabilization

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Adequacy (Cont.)	7. Line failures 8. Fixture staining 9. Water heater replacement	

pH of a saturated solution is generally 3.4 to 4.0 and solutions are corrosive. Piping, valves, pumps and fittings should be chosen with this in mind.

Fluorides are fed into a water supply as solids or liquids. For a description of the different types of chemical feeders and associated problems refer to Module 11.

Fluorides must be fed accurately in water treatment. A difference of 0.3 mg/1 below the optimum level will produce, on the average, one additional dental cary in 13 year-old children. The prolonged use of water containing fluorides in excess of the optimum level will produce some mottling (dental fluorosis).

Samples for fluoride analyses should be collected and analyzed once a day in small treatment plants, more often in larger ones. The results of the laboratory tests should be compared to the computed fluoride dose for each day.

Evaluation Issues for Fluoridation

Probably the most important evaluation issue is the correct dosage of the additive. The correct dosage in turn is a function of water quality monitoring of influent water, and the proper addition of dry chemicals or solutions. The evaluator should consult records for the appropriate calculations, and operational testing and also for proper preventive and corrective maintenance of dry and/or solution feeders.

Protection of chemical feed equipment should prevent contamination from dust. The evaluator should also check piping, valves, pumps and fittings for signs of corrosion when saturated solutions are employed.

These and other evaluation issues are summarized in Table 10.4 .

Iron and Manganese Removal

Iron and manganese are objectionable in public water supplies because of their effect on taste, staining of plumbing fixtures, spotting of laundry, and accumulation of deposits in distribution systems. Iron and manganese occur in their reduced states (Fe^{++} and Mn^{++}) frequently in groundwater and less frequently in surface waters. Since exposure to dissolved oxygen results in oxidation to the much less soluble hydrated metal oxides. However, surface

TABLE 10.4 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Fluoridation

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Description of equipment See Chemical Feed and Storage	To adjust the level of fluoride ion concentration to an optimum value		Adequacy	F within optimum range. 1. Use records of amount injected and volume of water treated. 2. Records of F ion tests of raw and finished water.	
			Continuous Service	1. Down time records. 2. Maintenance program. 3. Two week supply,min. inventory	

TABLE 10.4 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Treatment

Subfunction: Fluoridation

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Protection	1. Cross connection 2. Control against excessive feed.	
			Safety	1. Dust control where dry chemical is used 2. Personnel protection a) eye wash b) masks for dust c) skin pro tection 3. Proper ventilation appropriate	

TABLE 10.4 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Treatment

Subfunction: Fluoridation

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Safety (Cont.)	to chemical used.	

waters which do require iron and manganese removal are those typically derived from the hypolimnion of deep lakes or from eutrophic lakes where reducing conditions have developed to the extent that precipitated iron and manganese are returned to solution.

In addition to the hydroxide complexes other inorganic complexes may form where waters contain substantial amounts of bicarbonate, sulfate, phosphate, or halides. The formation of organic complexes may also increase the solubility of iron and manganese. While there are currently no analytic techniques which will determine "organic iron" or "organic manganese", there is no question that stable solutions or colloidal dispersions of iron and manganese can be prepared by the addition of organic acids to water.

The most common method of removing iron and manganese from municipal water supplies involves three basic steps: oxidation, detention, and filtration. Oxidation primarily serves the purpose of forming the less soluble hydrated metal oxides. Oxidation is most commonly accomplished by aeration or chemical oxidation with chlorine or potassium permanganate. In addition, it serves to reduce the carbon dioxide content of most ground waters, thereby increasing the pH. The aeration step may also be used to provide contact between the water and the oxidized precipitates attached to a contact surface. The contact aerator, which generally contains trays of coke, limestone, traprock, pyrolusite, or wooden slats, is most commonly used.

In municipal water-treatment practice, it is more common to remove iron and manganese by aeration and filtration prior to utilizing ion exchange for softening. Iron and manganese removal is, of course, incidental to softening by precipitation with lime-soda.

Strong oxidants, such as chlorine, chlorine dioxide, and potassium permanganate are employed chiefly where waters contain manganese. Breakpoint chlorination is found to result in slow precipitation of hydrated manganese dioxide unless a pH of 8.0 is exceeded. Oxidation by chlorine dioxide is faster; however, the pH will generally have to be kept above 8.5 to obtain effective manganese removal. Potassium permanganate will oxidize manganous ion to manganese dioxide over a broad pH range and rapidly (within 5 minutes). The dosage of $KMnO_4$ required for oxidation decreases with increasing pH.

The precipitation and agglomeration of iron and manganese is not instantaneous and detention must be provided following aeration to allow time both for oxidation to proceed and for oxidized iron and manganese to agglomerate to a filterable size.

The rate of oxidation of FE(II) by oxygen is slow under conditions of low pH as shown in Figure 10.3. If the removal of CO_2 does not increase the pH a sufficient amount, lime may be added. The accumulation of deposits on the contact aerator presumably acts as catalysts and increase the rate of oxidation.

Little sedimentation occurs in most detention basins. Instead most detention tanks may be considered to be a reaction basin. Filtration may be provided by either pressurized or gravity rapid sand filters.

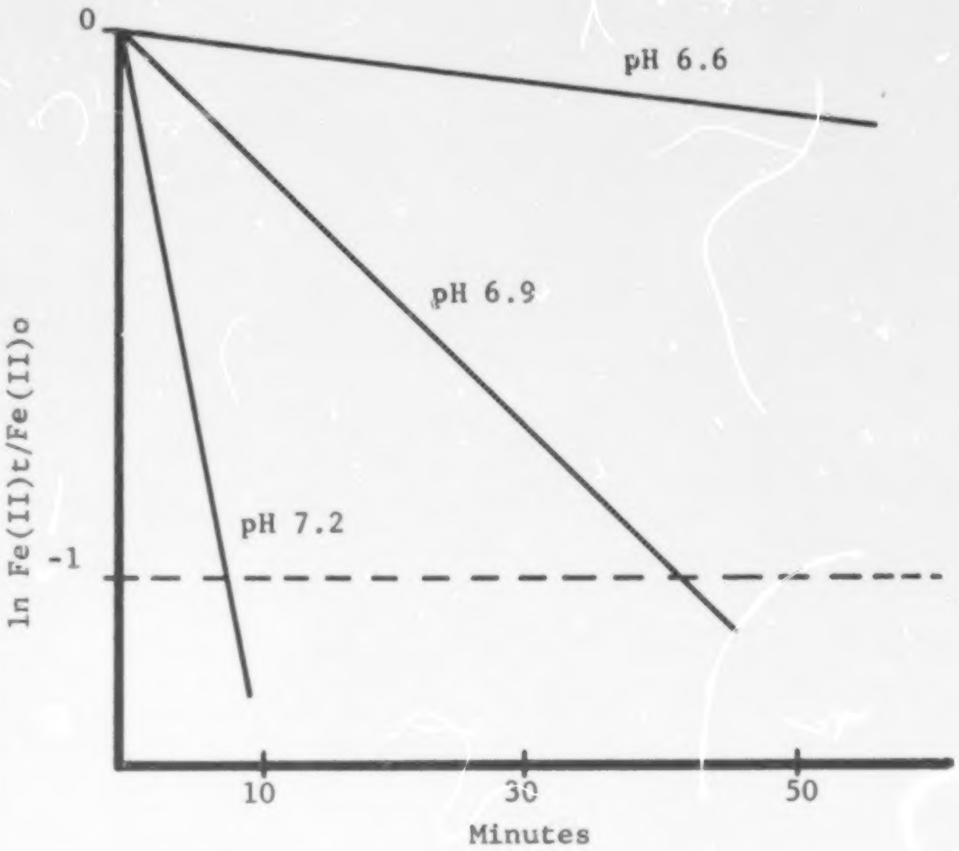
The performance of an efficient iron removal process is shown in Figure 10.4. The ferrous iron is almost completely oxidized after detention. The resulting ferrous iron is removed by filtration.

While not common, the removal of iron and manganese may be accomplished by continuously regenerated permanganate green sand filters. Aeration is avoided as potassium permanganate is continuously added to the raw groundwater prior to passage through a bed of zeolite (greensand) exchange medium. The permanganate oxidizes the iron and manganese so that the exchange medium becomes coated with the oxidation products. The hydrous oxides of iron and manganese deposited on the exchange medium have a large sorption capacity for Fe(II) and Mn(II). This capacity makes it possible to operate the filter on an intermittent basis, regenerating with $KMnO_4$ after the exchange capacity is exhausted, to oxidize the adsorbed Fe(II) and Mn(II).

Evaluation Issues for Iron and Manganese Removal

Evaluation issues pertaining to aeration are included under the section entitled "Aeration", and to filtration, under the section entitled "Filtration".

Additional evaluation issues pertinent to iron and manganese and their removal include (1) concentrations of these ions in raw and finished waters, (2) detention time, (3) filtration and backwash rates, (4) the protection of treated waters from cross-connections, and (5) the protection of treated waters indicated by the "pink" appearance of permanganate in solution.

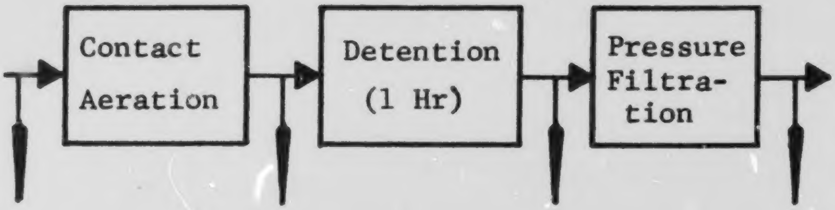


$$\frac{-d\,[Fe(II)]}{dt} = K\,[Fe(II)]\,[O_2]\,[OH^-]^2$$

$$\frac{-d\,[Fe(II)]}{dt} = K'\,[Fe(II)]$$

$$\ln \frac{[Fe(II)]t}{[Fe(II)]o} = -K'\,t$$

Figure 10.3 pH Dependence of Fe(II) Oxygenation (Adapted from: American Water Works Association, 1971. Water Quality and Treatment. 3rd Edition, AWWA, Denver, Colorado).


Contact Aeration
Detention (1 Hr)
Pressure Filtration

DO	0.0	8.0	8.0	0.2
Fe(II)	3.0	1.5	0.1	0.1
Fe(III)	0.0	1.5	3.0	0.0
pH	7.2	7.6	7.6	7.4

Figure 10.4 Changes in Parameters during the Iron Removal Process (Adapted from: American Water Works Association, 1971. Water Quality and Treatment. 3rd Edition, AWWA, Denver, Colorado).

These evaluation issues are summarized in Table 10.5 .

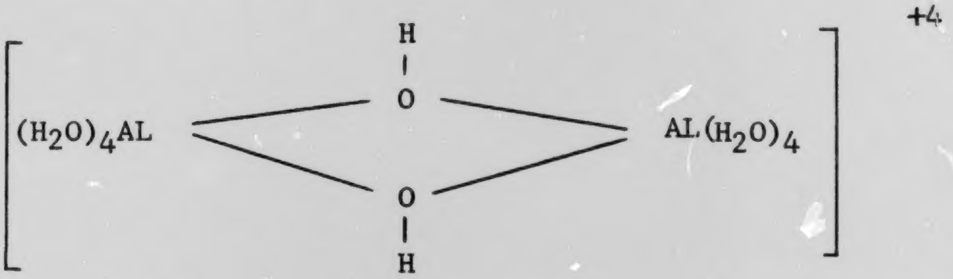
Coagulation - Flocculation

Historically, the terms "coagulation" and "flocculation" have been used indiscriminately to describe the process of removal of turbidity from water. However, there is a clear distinction between these terms.

The coagulation process is the process set in motion by the addition of a chemical to a colloidal dispersion and which results in particle destabilization by a reduction of the forces tending to keep the particles apart.

The flocculation process is the process by which settleable particles are formed from the destabilized colloidal-sized particles.

Aluminum and iron salts have long been used as coagulants. When added to water, these metals will react with the water or with the alkalinity in water. Aluminum ions enter into a series of hydrolytic reactions with water to form multivalent charged hydrous oxide compounds. These compounds will have a net positive charge at low pH values, and a net negative charge at high pHs. A second type of reaction that occurs and results in a chemical complex containing several aluminum ions as follows:



In a similar way, iron undergoes a series of reactions with the ultimate formation of ferric complexes:

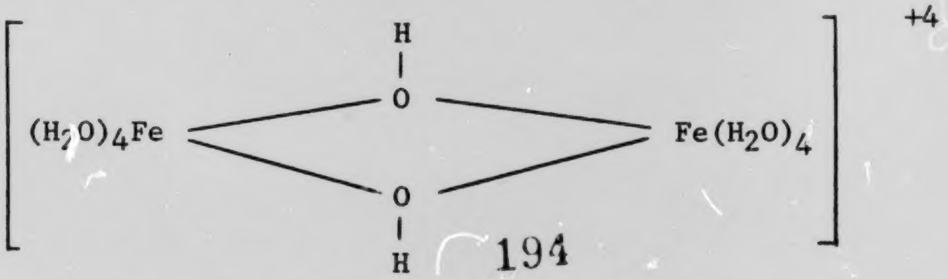


TABLE 10.5 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Iron and Manganese Removal

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Overall System	Remove Fe & Mn		Adequacy	Fe $<$ 0.3 ppm Mn $<$ 0.05 ppm	
Aerator 1. Describe	Oxidation to insoluble form		See form on Aeration		
Detention Basin 1. Describe	Allow oxidation process to go to completion		Adequacy	Detention time $>$ 20 min.	
Filtration	Remove Precipitate	See Section on Filtration, Module 10.			
Green Sand Tank 1. Describe	Remove Fe & Mn in solution		Adequacy	1. Fe $<$ 0.3, Mn $<$ 0.05 2. Filtration rate vs. design rate	

TABLE 10.5 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Treatment

Subfunction: Iron and Manganese Removal

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Backwash Method 2. Describe	Remove solids and regenerate green sand media		Adequacy	1. Backwash rate vs. design 2. Frequency	
			Protection	1. Cross Connection check 2. Pink water	

The important characteristic about these reactions is that both hydrogen and hydroxide ions are involved. Therefore, pH is an important factor in producing these coagulants.

Once produced, these coagulants are readily adsorbed onto the surface of turbidity (generally clay turbidity) particles. This coating of turbidity particles with the coagulants is due to the electrostatic attraction between clay particles and the coagulants and acts to reduce the overall charge between particles, thus allowing the particles to agglomerate to settleable size (i.e., flocculate).

Unlike clay turbidity, however, other materials in water (including those causing natural color) actually combine chemically (not electrostatically) with coagulant species (pH 4.0 - 6.0) forming insoluble products that either have a neutral charge or are destabilized, and thus capable of agglomerating.

For a given water, there will be interrelated optima of conditions of pH, turbidity, chemical composition of the water, type of coagulant, temperature, and mixing. The proper dose and physical conditions for coagulation must be determined empirically for each water.

Rapid or flash mixing is the process by which the coagulant is rapidly and uniformly dispersed in water. It usually occurs in a basin immediately preceding or at the head end of the coagulation basin. Flocculation usually occurs in the mixing or flocculation basin.

A variety of materials have been used to aid clarification, including (1) oxidants, (2) adsorbents - weighting agents, (3) activated silica, and (4) poly-electrolytes. Oxidants (including chlorine, chlorine dioxide, ozone and potassium permanganate) have proven useful when there are difficulties with clarification due to dissolved organic materials. These oxidants are added prior to coagulation when their function is to aid coagulation.

Bentonitic clays are used in treating waters with high color, low turbidity, and low mineral content. The floc produced from highly colored waters by iron or aluminum coagulants is often too light to settle rapidly. The addition of clay results in a "weighting action", and floc then settles rapidly. The clay also serves to increase the frequency of particle collisions, resulting in rapid formation of settleable floc. Other weighting agents include powdered silica, limestone, and activated carbon.

Activated silica is generally added after the alum (although it has also been used prior to the addition of alum). Activated silica offers several advantages: (1) increased rate of coagulation, (2) reduced coagulant dose, (3) extended pH range of coagulation, (4) increased rate of flocculation, (5) produces larger and denser flocs, (6) toughens the floc so that filtration is improved, (7) more effective coagulation at low temperatures, (8) improved removal of color, (9) improved flocculation of high-turbidity waters, and (10) reduction of colloidal matter passing filters.

Synthetic polyelectrolytes are of three types: anionic (negatively charged); cationic (positively charged), and nonionic (neutral charge). The major benefit obtained from polyelectrolytes is a very large increase in floc size, and the consequent increased settling rate of the floc. Anionic polyelectrolytes perform as flocculants only with the addition of metal coagulants. Cationic types perform as flocculants without the addition of metal coagulants, although this usually results in high residual turbidity.

Laboratory and in-plant control are essential to proper coagulation treatment. The coagulation and flocculation of water is influenced by pH, color, turbidity, mineral content, temperature, duration and degree of agitation, and the coagulant or flocculation aid used. The optimum conditions of these variables cannot be determined on the basis of theory.

The most commonly used test to determine dosage and other parameters is the "jar test". This test simply consists of a series of sample containers, the contents of which can be stirred by individual mechanically operated stirrers. Water to be treated is placed in the containers, and the treatment chemicals are added while the contents are stirred. The range of conditions (e.g., pH, coagulant dose, etc.) are selected to bracket the anticipated optima. This test, as well as a number of others, will be discussed by your instructor under Module 13.

Evaluation Issues for Coagulation - Flocculation

As indicated in the following table, the objectives of coagulation - flocculation are to provide instant dispersion of chemicals (coagulants, coagulant-flocculant aids), and to permit the floc to develop. Floc size is an important criterion for evaluating the adequacy of the clarification process. In addition, the evaluator should evaluate the clarity of the effluent (after sedimentation) to ensure that proper coagulation - flocculation has taken place. Laboratory records, including the results of jar tests, are an important means of evaluating the overall efficiency of the clarification process. Additional records, including maintenance records, and operational records for detention time, should be examined. See Table 10.6 .

Sedimentation

Sedimentation is the process by which coagulated or suspended matter separates from water by subsidence and deposition. This process occurs in the sedimentation basin, sometimes referred to as the settling basin or settling tank.

The most common forms of sedimentation basins are circular, square or rectangular. The majority are rectangular in shape and of reinforced concrete construction. Most basins have sloping bottoms to facilitate the removal of deposited sludge, or have mechanical drag devices for the removal of sludge (Figure 10.5).

Inlets into basins must distribute coagulated water uniformly among the basins and uniformly over the cross section of each sedimentation basin. The permissible velocity range for any water and floc can be determined by tests, but velocities between 0.5 and 2.0 fps are usually satisfactory. Properly designed inlets and outlets are necessary to avoid short-circuiting through the basin.

Baffles are sometimes used in sedimentation basins to reduce short-circuiting and to improve settling efficiency. This may, however, also produce eddy currents and cause disturbance of the deposited solids.

Water leaving the basin should be collected uniformly across the width of the basin in order to prevent high velocities and therefore the lifting of settled sludge.

The time theoretically required for a volume of water to flow through a sedimentation basin is called the "detention time". It is equal to the time required to fill the basin at a given rate of flow and can be computed by dividing the volume of the basin by the rate of flow through it.

The desireable detention time is affected by the purpose of the basin. In a plain sedimentation basin, depended upon for removal

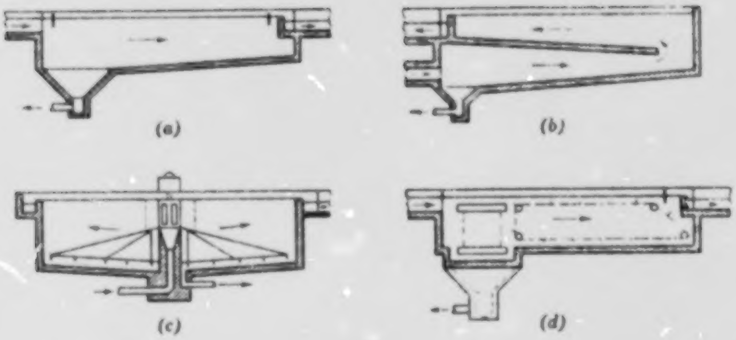
TABLE 10.6 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Coagulation - Flocculation

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Rapid Mix Description 1. Method of mix 2. Location 3. Size	Provide instant dispersion of chemical		Adequacy	1. Floc size 2. Clarity of sedim. effluent 3. Mainten - ance records	
			Protection	1. Cross Connection	
Flocculation Tanks Description 1. # & size 2. Flocculators	Permit floc to develop		Adequacy	1. Jar tests 2. Detention time 3. Maintenance records 4. Floc size	



(a) Rectangular tank with longitudinal flow. Tank is thrown out of operation for cleaning. Solids are flushed to sump for removal from the dewatered tank. (b) Tank a, equipped with a single tray. (c) Circular tank with radial flow. Solids are plowed to central sump and withdrawn during operation. The rotary mechanism carries plows. (d) Tank a, mechanized. Solids are scraped to influent end, thence to sump to be withdrawn during operation. In some designs the solids are collected at the effluent end.

Figure 10.5 Representative Designs of Horizontal-Flow Settling Tanks. (Adapted from Fair, G.M., Geyer, J.C., Okun, D.A. 1968. Water and Wastewater Engineering, Volume 2. John Wiley & Sons, Inc., New York, New York.)

of fine suspended solids, the detention time must be long - in fact, the longer the better. In a properly designed basin that receives well-coagulated water, a detention time of from 2-4 hours is usually ample to prepare the water for filtration.

In manually cleaned basins, coagulated matter may be allowed to accumulate until it tends to impair the settled-water quality, at which time the sludge is flushed out. In basins having sloping bottoms, most of the sediment flows out with the water. Because the bulk of the material settles near the inlet end, the floor scoop should be greater at this point. The time between cleanings varies from a few weeks (in plants having turbid water and short periods of settling) to a year or more (where basin capacity is large and water is not very turbid). Sometimes decomposition of sediments makes it desireable to clean the basin more frequently. However, decomposition of some sludges can be controlled by prechlorination or other chemical treatment.

Sedimentation basins may be equipped with sludge collection and removal mechanisms to maintain volumetric efficiency and reduce the need to shut down for cleaning. Circular and square tanks may be provided with rotating mechanisms having rakes and blades that push the sediment to a central point where it can be flushed out. Rectangular basins may have one or two basic types of collectors: a series of chains and sprockets which are mounted at the top and bottom of the tank with wood or steel cross members which scrape the tank bottom; or a carriage mount system which travels along the wall of the tank, does not have wearing parts under water, and which is therefore less subject to shutdown.

All removal equipment must be designed to withstand that highly abrasive action of sludge.

Some basins are designed so as to combine mixing, flocculation, conditioning, clarification and sludge removal in a single unit. Such tanks are referred to as "solids contact process tanks" (See Figure 10.6). A major advantage of these tanks is the compactness of the units. They require less space and may be less costly to install. However, because of their unitized nature, they have less operating flexibility.

Evaluation Issues for Sedimentation

As discussed above, important parameters involved in sedimentation are the velocity of flow and detention time. The

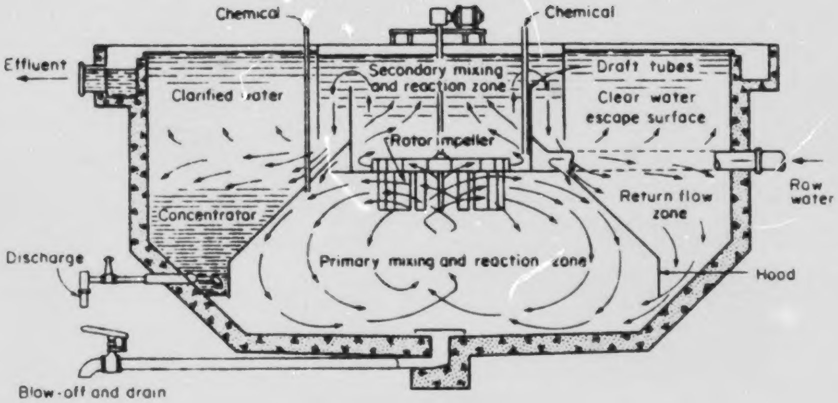

Chemical
Chemical
Effluent
Secondary mixing and reaction zone
Draft tubes
Clarified water
Clear water escape surface
Rotor impeller
Raw water
Return flow zone
Concentrator
Discharge
Primary mixing and reaction zone
Hood
Blow-off and drain

Figure 10.6 An Accelerator, Combining Chemical Mixing, Reaction, Floc Concentration, and Clarification. Adapted from American Water Works Association, Inc., 1971. Water Quality and Treatment. Third Edition. McGraw Hill Book Company, New York, New York.

evaluator should review these parameters in light of standard operating practices, and in light of finished water quality, including the turbidity and color of settled-water effluent. The evaluator should also inspect filters that filter settled-water effluent in order to identify obvious inefficiencies in the settling process. The frequency of sludge removal should be reviewed in light of design specifications, effluent water quality, and obvious problems associated with the decomposition of settled floc. These issues are summarized in Table 10.7 .

Filtration

Filtration is the passage of a fluid through a porous medium to remove matter held in suspension. In water purification, the matter to be removed includes suspended silt, clay, colloids, and microorganisms. A filter may consist of a thin porous layer of filter aid deposited by flow on a support septum, or a bed of granular non-porous material held in place by the force of gravity or by the direction of flow.

Floc particle size and strength are of basic importance to the filtration process. Floc particle size may range from 2.0 mm down to sizes of less than 0.1 mm. The larger floc particles can be removed by simple straining of the bed surface, but the smaller particles will pass into the bed and lodge within it. Unless the flocs are strong, those that lodge in the bed by simple straining will break as the hydraulic gradient increases.

Three basic types of filters are in general use: slow sand filters, rapid sand filters, and pressure filters. A fourth type, diatomaceous-earth filters, has more limited use.

Slow sand filters are historically the oldest type of filter used for municipal treatment. Because of the low rate of filtration in these beds, the filter beds had to be quite large to deliver enough water to fair-sized towns. Toward the end of the 19th century another type of sand silter was introduced (the rapid sand filter). These rapid sand filters can be operated about 30 times faster than the slow sand filters. Rapid sand filters were constructed for the treatment of turbid river waters; slow sand filters nevertheless continue to be utilized wherever raw-water quality and economics of construction and operation favor their use. The general features of rapid and slow sand

TABLE 10.7 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Sedimentation

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Settling Tank Description 1. Shape 2. Size 3. Flow pattern 4. Means of solids removal	Solids removal by settling		Adequacy	1. Turbidity <1.0 2. Color < 15 3. Filter condition 4. Clarity of effluent 5. Vel. of flow and detention time	
Solids Contact Process Tank	Solids removal by gravity		Adequacy	1. Same as above	
Sludge Collection Device	Concentrate and accumulate particles removed by settling		Adequacy	1. Frequency of sludge removal required	

filters are compared in Table 10.8.

Because the objective of filtration is to separate suspended matter from water, measurement of the remaining suspended matter is essential. Bacterial determinations are important tools for estimating filtration efficiency and should be made routinely. But the most useful criterion for the control of the filtration operation is turbidity. Turbidity may, of course, be measured in laboratory turbidimeters, but there are two more-rapid methods available for control of the filtration operation: (1) the illuminated sightwell, and (2) the continuous flow light-scattering nephelometer. These procedures will be discussed in class.

Natural run-of-bank sand may be too coarse, too fine, or too non-uniform for a filter. Specified sizing and uniformity is obtained by screening out coarse grains and washing out fines. Rapid filters may be composed of natural silica sand, crushed anthracite, crushed magnetite and garnet sands. If the sand grains are small in size, or if the floc is tough, the penetration of flocculated material beneath the sand surface may be small. However, upon continued operation of a rapid sand filter, channels will appear in the filter medium and coagulated material will penetrate into the bed. When there is little penetration, the filter loss of head increases rapidly, and the filter runs are too short for practical operation. When penetration is greater (2-4 inches in a single medium bed), flocs pass down into coarser underlying layers, and there is danger of breakthroughs.

Hydraulic effects of floc penetration and accumulation as well as of other phenomena associated with filters lead to a variety of problems in rapid sand filters. For example, because resistence to flow is least along the walls of a filter, less head is lost there, and resulting pressure differentials within the bed establish inward as well as downward flows. Filter grains are subsequently pushed away from the walls and water short-circuits through resulting shrinkage cracks and fills them with cake.

Another problem associated with rapid sand filters is "mud balls". These are conglomerations of coagulated turbidity, floc, sand and other binders. They collect on the surface, grow in size, and increase their density. Eventually they become heavy enough to migrate downward as far as the gravel where they accumulate and clog portions of the bed. They should therefore be

	Slow Sand Filters	Rapid Sand Filters
Rate of filtration	1 to **3** to 10 mgad	100 to **125** to 300 mgad†
Size of bed	Large, ½ acre	Small, 1/100 to 1/10 acre
Depth of bed	12 in. of gravel; 42 in. of sand, usually reduced to no less than 24 in. by scraping	18 in. of gravel; 30 in. of sand, or less; not reduced by washing
Size of sand‡	Effective size 0.25 to **0.3** to 0.35 mm; coefficient of nonuniformity 2 to **2.5** to 3	0.45 mm and higher; coefficient of nonuniformity 1.5 and lower, depending on underdrainage system
Grain size distribution of sand in filter	Unstratified	Stratified with smallest or lightest grains at top and coarsest or heaviest at bottom
Underdrainage system	Split tile laterals laid in coarse stone and discharging into tile or concrete main drains	(1) Perforated pipe laterals discharging into pipe mains; (2) porous plates above inlet box; (3) porous blocks with included channels
Loss of head	0.2 ft initial to 4 ft final	1 ft initial to 8 or 9 ft final
Length of run between cleanings	20 to **30** to 60 days	12 to **24** to 72 hr
Penetration of suspended matter	Superficial	Deep
Method of Cleaning	(1) Scraping off surface layer of sand and washing and storing cleaned sand for periodic resanding of bed; (2) washing surface sand in place by washer traveling over sand bed	Dislodging and removing suspended matter by upward flow or backwashing, which fluidizes the bed. Possible use of water or air jets, or mechanical rakes to improve scour
Amount of wash water used in cleaning sand	0.2 to 0.6% of water filtered	1 to **4** to 6% of water filtered
Preparatory treatment of water	Generally none	Coagulation, flocculation, and sedimentation
Supplementary treatment of water	Chlorination	Chlorination
Cost of construction, U.S.A.	Relatively high	Relatively low
Cost of operation	Relatively low where sand is cleaned in place	Relatively high
Depreciation cost	Relatively low	Relatively high

* The most common values are shown in boldface type.

† 125 mgad = 2 gpm per sq ft = 16 ft per hr = 125 m per day.

‡ For a definition of sand size terms, see Sec. 27-4.

Table 10.8 General Features of Construction and Operation of Conventional Slow and Rapid Sand Filters. Adapted from: Fair, G.M., Geyer, J.C., Okun, D.A. 1968. Water and Wastewater Engineering, Volume 2. John Wiley & Sons, Inc., New York, New York.

removed or broken up while they are small and light.

A third problem related to the hydraulics of filter operation is referred to as "jetting" and "sand boils". Differences in porosity and permeability of sand and gravel (enhanced by clogging, mud balls, etc.) cause backwash waters to follow the path of least resistence and break through the surface of the bed at scattered points. Where flow occurs, the clogged and compressed sand is fluidized, back pressure is reduced, flow increases, and water is jetted from the gravel to the sand. With severe jetting, the sand boils up, and both sand and gravel are lifted to the surface.

Where there is any gravel failure, sand leakage can occur. If the loss of sand to the gravel continues, persists or increases over a short period of time, it is apparent that the gravel layers have been seriously upset and it is necessary to rebuild the filter media or correct any other trouble that may be the cause of the sand leakage.

Pressure filters are based on the same principle of rapid-sand filters, but the underdrains, gravel, and sand are placed in a cylindrical tank, and water is passed through the filter under pressure (Figure 10.7). Filters of this type are used where raw water is supplied under pressure and where it is desireable to filter and deliver water without further pumping. Pressure filters are subject to most of the operating difficulties that afflict standard rapid filters.

Diatomaceous-earth filters are generally used as mobile units for water purification in the field, and as stationary units for swimming pools and general water supplies. The filtering mechanism is a layer of diatomaceous earth built upon a porous septum when a slurry of diatomaceous earth is recirculated through the septum until a firm layer is formed. Water is then strained through this layer (pre-coat) unless the water contains so much turbidity that the unit will function only if additional diatomaceous earth is put into the incoming water to preserve the open texture of the layer.

Evaluation Issues for Filtration

The following three tables 10.9, 10.10, and 10.11 summarize the important evaluation parameters for rapid and slow sand filters, and for pressure filtration units. In each case, these

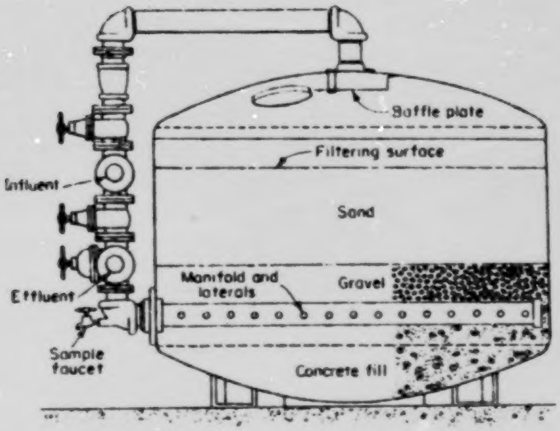

Baffle plate
Filtering surface
Influent
Sand
Effluent
Manifold and laterals
Gravel
Sample faucet
Concrete fill

Figure 10.7 Cross Section of Typical Pressure Filter. Adapted from: American Water Works Association, Inc. 1971. Water Quality and Treatment. Third Edition. McGraw Hill Book Company, New York, New York.

TABLE 10.9 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Rapid Sand or Media Filtration

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Filter Description 1. # of filters 2. Area of each 3. Depth of media 4. Type of media a) sand b) anthracite c) mixed media d) inverted media	Remove Suspended Solid Materials		Adequacy	1. Turbidity < 1.0 2. Color <15 clarity in clear well 3. Rate of flow (2-3 gpfm sand) (4-5 gpfm mixed) 4. Length of filter run 5. Observe backwash (15 gpfm) a) frequency b) even trough overflow c) air binding 6. Media condition a) level b) mudballs	

TABLE 10.9 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Rapid Sand or Media Filtration

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Adequacy (Cont.)	c) channeling d) sand growth e) sand loss f) cementing 7. Maintenance records a) valves b) media c) rate controllers	
			Protection	1. No common walls 2. Cross connection (surface wash) 3. Bypass	

TABLE 10.10 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Slow Sand Filtration

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Filter Description 1. Media 2. Area 3. Media depth	Remove suspended material from water		Adequacy	1. Turbidity <1.0 2. Color <15 3. Rate of flow (5.0 mgd/acre)	
			Continuous Service	1. Frequency and method of media cleaning	
			Protection	1. Bypass	

TABLE 10.11 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Pressure Filtration

Objective:

1 System Component	2 Component Objective	3 Responsible Person for Component	4 Evaluation Objective	5 Evaluation Criteria	6 Evaluation Conclusion
Filter Tank Description 1. Dimensions 2. Media used 3. Pressure	Remove suspended solids from water		Adequacy	1. Turbidity <1.0 2. Color <15 3. Flow rate (2-3 gpfm) 4. Filter run (6-8 ft loss of head) 5. Frequency of backwash 6. Maintenance a) valves b) media inspection 7. Observe backwash	
			Protection	1. Bypass	

parameters of adequacy, continuous service and protection include (1) water quality parameters of effluent water, (2) flow rates and durations, (3) maintenance parameters, and (4) other conditions and characteristics of the filtration operation. The evaluator should ensure that each of the identified parameters conforms to promulgated standards and regulations, and to standard operational practice.

Disinfection

Disinfection is the purposeful killing of such organisms as bacteria, viruses and amoebic cysts which can infect human populations by their transmission through water.

There is a variety of physical and chemical disinfectants, including heat, light, metal ions, alkalis and acids, surface-active chemical, and oxidizing agents. The most effective and easily utilized disinfectants in water supply systems are oxidizing agents.

The efficiency of disinfection by oxidizing chemicals appears to depend upon their penetration of the cell walls of target-organisms and chemical inactivation of enzymes which are essential for the continuance of life processes in the cell. Various conditions are generally recognized for their influence on the killing-capacity of oxidizing chemicals, including:

(1) The nature of target organisms, their concentration, distribution and condition in the water to be disinfected,

(2) The nature, distribution, and concentration of the disinfectant (and its reaction products) in the water,

(3) The nature and condition of the water to be disinfected (including temperature,pH, and other chemical, physical, and biological characteristics), and

(4) The period of contact between the disinfecting agent and the target organism.

In addition to high disinfecting efficiency, practical disinfectants should also be characterized by:

(1) non-toxicity and non-obnoxiousness to humans and domestic animals,

(2) reasonable cost, ease and safety in handling,

(3) ease by which concentrations can be determined and regulated, and

(4) residual protection.

Chlorination is the most important means of disinfection. When chlorine is added to water, a variety of reaction products is formed. Some of these products are powerful disinfectants: The most efficient disinfectants made available by mixing chlorine and water include hypochlorous acid (HOCl), hypochlorite ion $(OCl)^-$ and elemental chlorine, collectively referred to as free available chlorine. The relative amount of these species of chlorine depends on pH and temperature. Elemental chlorine lasts only very briefly at pH's greater than about 3; at pH's above 8.5, over 90% of the chlorine species will be in the form of hypochlorite ion, and at pH's below 6.5, over 90% will be in the form of hypochlorous acid. The killing efficiency of HOCl is greater than that of $(OCl)^-$. Therefore lower pH's are conducive to more efficient disinfection. Higher temperatures, as is generally the case, also promote disinfection.

Free available chlorine can react with a variety of inorganic and organic materials in water, as well as with target organisms. For example, chlorine can react with Fe^{++}, Mn^{++}, NO2, and H_2S and change into chloride ions. Furthermore, it can react with both living and dead materials to produce a variety of organic chlorides. These reaction products are not disinfectants. However, reactions of chlorine species with organic amines produce complex organo-chloramines which can be toxic to a variety of aquatic organisms. Reactions of hypochlorous acid with ammonia also produce inorganic amines (including monochloramine, and dichloramine), referred to collectively as combined available chlorine. As indicated in Figure 10.8, combined available chlorine does accomplish disinfection. However, combined available chlorine is less efficient in disinfection than is free available chlorine.

The chlorine demand of water is the difference between the amount of chlorine added to the water, and the amount of free available and combined available chlorine remaining in the water

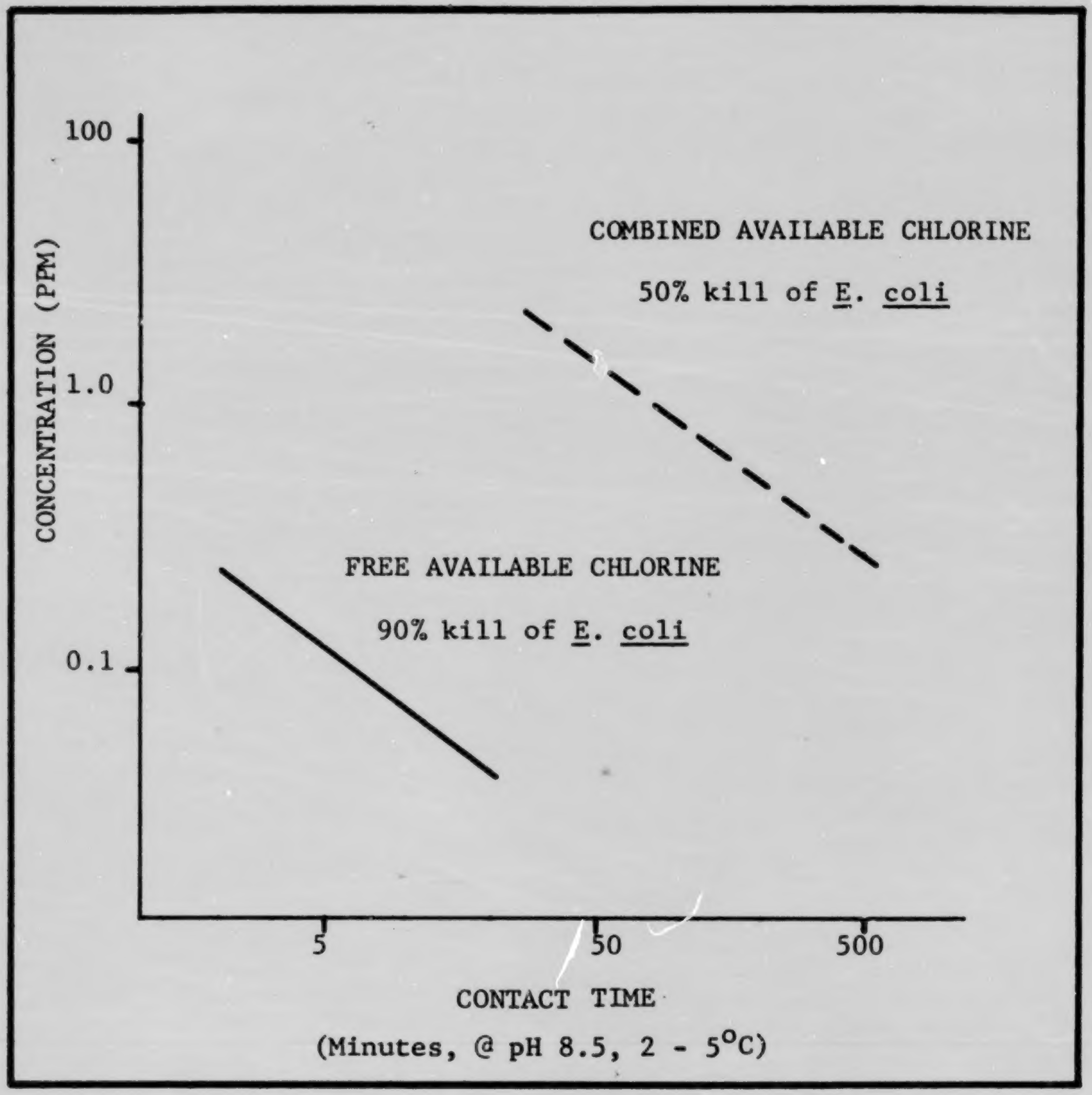


Figure 10.8 Comparison of Free Available and Combined Available Chlorine (Adapted from Fair, Gordon, Geyer, J.C. and Okun, D.A. 1968. Water and Wastewater Engineering. John Wiley & Sons, Inc. New York, New York.)

after some defined period of time. Chlorine demand depends upon time of contact, pH, and temperature. Because the amount of chlorine species remaining in the water is a function of reactions which produce inorganic and organic chlorides as well as disinfection reactions, the satisfaction of a high chlorine demand does not necessarily mean that there is rigorous disinfection.

Since free available chlorine is a more effective disinfectant than combined available chlorine, water treatment facilities often employ a procedure referred to as breakpoint chlorination. Breakpoint chlorination is comprised of two steps:

(1) the addition of chlorine to water until the chlorine demand has been satisfied, and

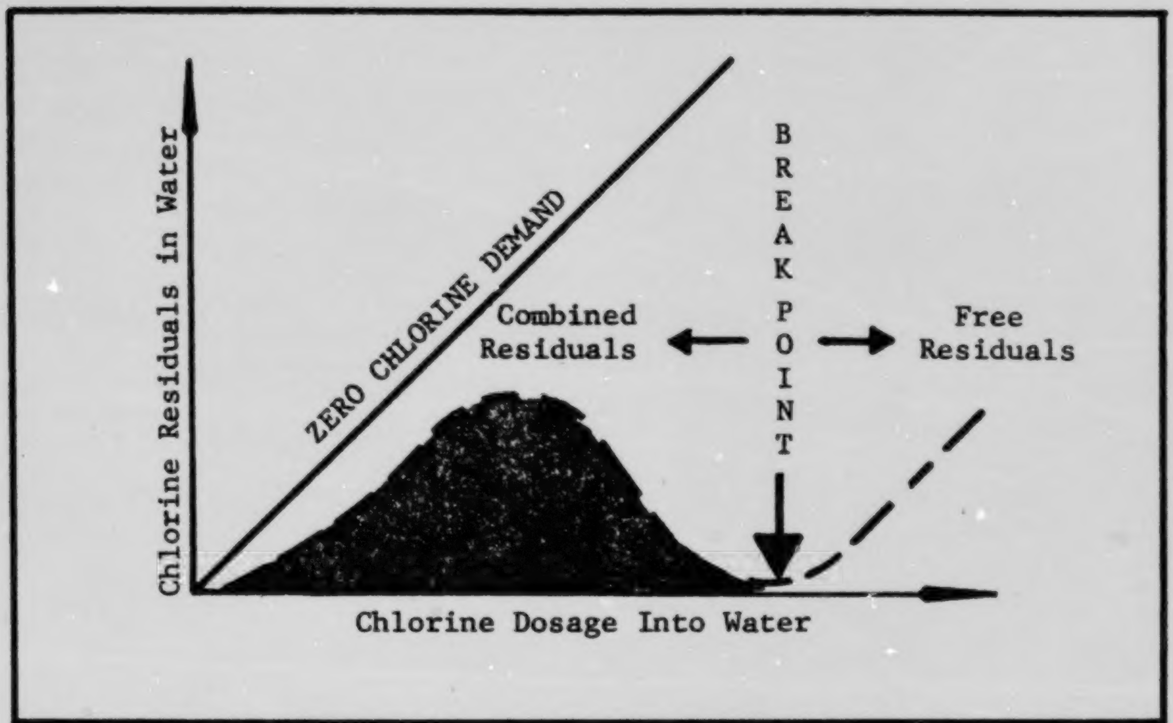
(2) the further addition of chlorine until the residual is directly proportional to the amount added beyond the breakpoint.

In water having an organic content (Figure 10.9), chlorine dosage of water up to the breakpoint results in the production of combined available chlorine species. At dosages greater than the breakpoint dosage, the chlorine species are those of free available chlorine. pH is a very important factor governing the rate of the breakpoint reaction. Typically, 30 minutes or more are required at a pH of 6.5 - 8.5 .

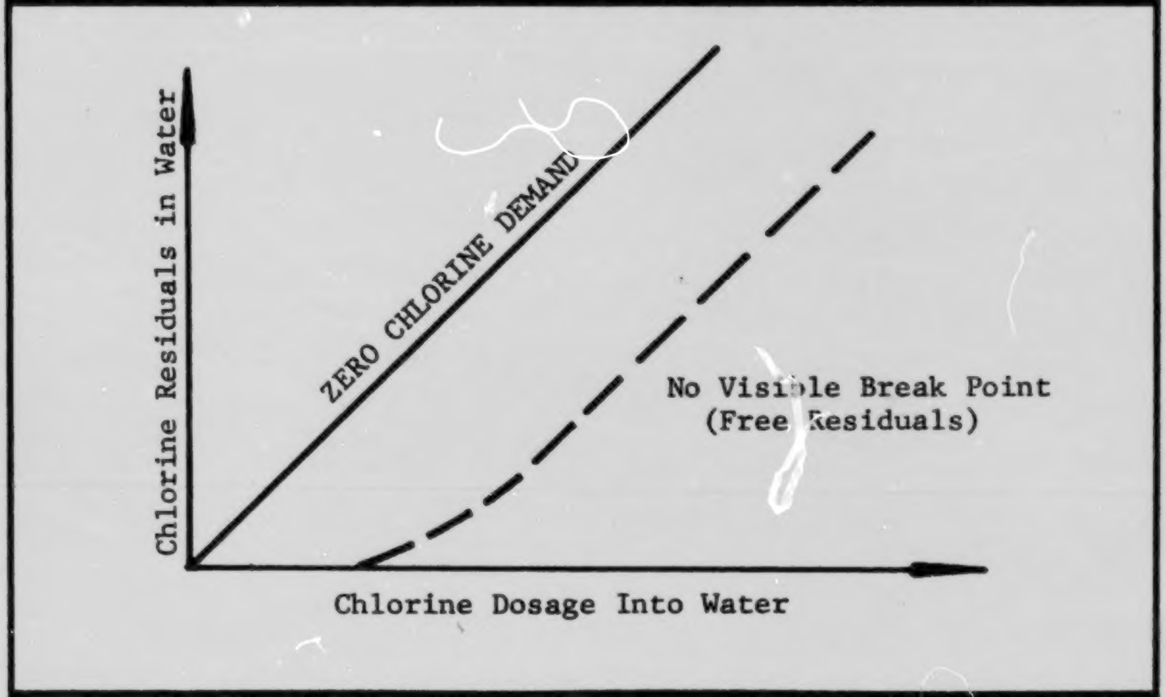
It is important to emphasize that breakpoint chlorination assures rigorous disinfection. It also destroys most obnoxious odors and tastes. However, in order to maintain breakpoint conditions, frequent testing must be made to determine breakpoint dosage.

Sodium chlorite (flake or powder) is soluble in water, and readily reacts with chlorine to produce a chlorine dioxide solution. Chlorine dioxide solution has been important for over 30 years for the control of phenolic tastes and odors. While chlorine dioxide is as bactericidal as chlorine, it is only rarely employed for disinfection. This is due to cost and the lack of a satisfactory residual test at low concentrations.

Because of its instability, ozone is usually generated at its point of use. While ozonation of water effectively reduces taste, odor and color problems and effectively disinfects (Figure 10.10) over a wide temperature and pH range, ozonation also has some



A: Chlorine Residual Curve for Water With [illegible] Content



B: Chlorine Residual Curve [illegible] Content

Figure 10.9 Examples of Chlorine Residual Curves.

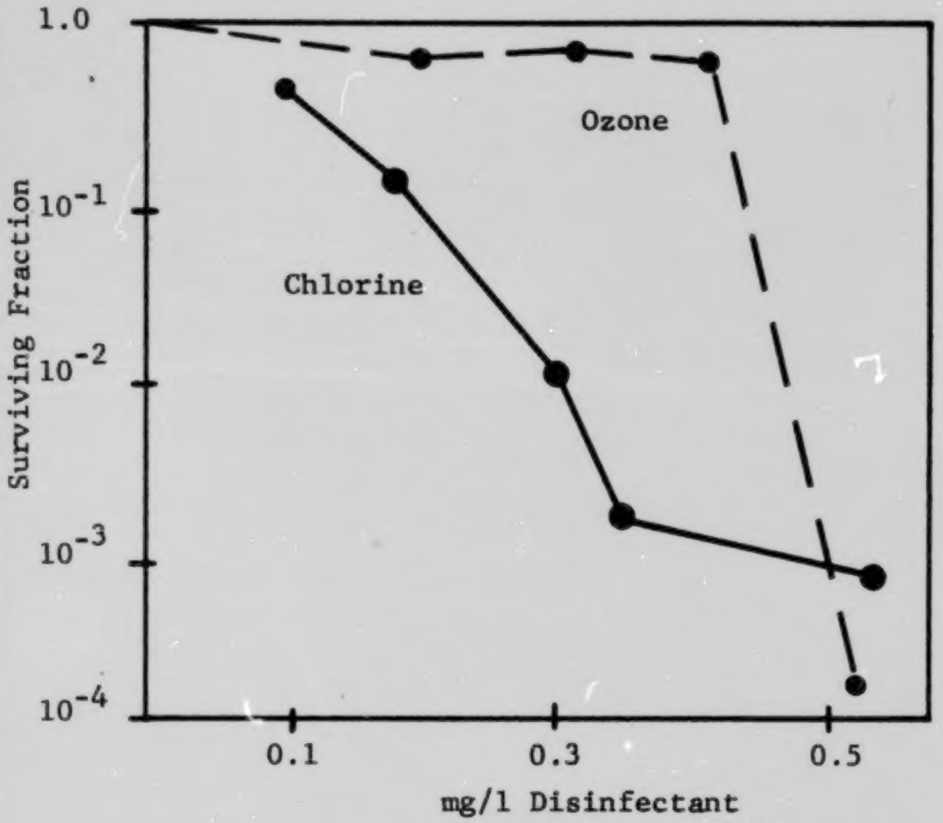


Figure 10.10 Concentration Dependence of Disinfection with Chlorine and Ozone (Adapted from: G. Fair, J. Geyer, and D. Okun, 1968. Water and Wastewater Engineering, Volume 2, John Wiley and Sons, New York, New York).

important disadvantages. These disadvantages include: (1) no lasting residual disinfection-action, (2) process is less flexible than chlorine in adjusting for flow rate and water quality variation, (3) analytical techniques are not sufficiently specific for ready and efficient control of the process, (4) electric energy requirements, and capital and operating costs are high, and (5) water with high organic content usually requires thorough pretreatment to satisfy the ozone demand.

Iodine may also be employed as a disinfectant. Important advantages of iodine include: (1) bactericidal action is not greatly influenced by pH except at very low temperatures, (2) nitrogenous impurities in water have little effect on germicidal effectiveness, (3) action depends less on contact-time and temperature than for chlorine, and (4) effective with short contact-time at relatively low dosages. However, the use of iodine as a disinfectant also has some important disadvantages including: (1) higher concentrations than for chlorine are necessary for comparable disinfection, (2) costs are about 20 times higher than chlorine per unit of germicidal effectiveness, (3) taste and slight color decrease palatability and aesthetic quality of water, and (4) physiological effect of prolonged use, especially in children, is still unknown.

Evaluation Issues for Disinfection

Evaluation issues for both liquid and gas-chlorination are essentially the same, except for the issue of safety with respect to gas-chlorination.

The adequacy of chlorination (for both liquid and gas chlorination) includes (1) the proper location, handling, and use of chlorine, (2) the schedule of resupply with respect to the rate of consumption, and (3) the proper points of application. Chlorine is a highly reactant material and should be stored in such a place and manner as to ensure personnel and plant safety. The evaluator must consult records in order to ensure that rates of usage (including both normal and emergency usage) do not outstrip resupply. Particular attention should be given to administrative mechanisms which guarantee adequate supply even under emergency conditions. This might require the evaluator to ensure that responsible operators know the sources of supply. Finally, the point of application should be evaluated with respect to standard practice, and required operational testing. Such testing will

TABLE 10.12 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Liquid Chlorination

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Chlorine Storage and Applica. Room 1. Configuration 2. Size	Efficient Handling and Application of Chlorine		Adequacy	1. Storage vs use 2. Use pattern vs. resupply 3. Points of Applic.	
Chlorinators 1. Make and applic. range	Apply chlorine to meet demand		Adequacy	1. Chlorine resid. maintained 2. Max demand vs avail. feed rate 3. Complaints 4. pH 5. Maintenance records	
			Protection	1. Cross connection	

TABLE 10.12 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Liquid Chlorination

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Continuous Service	1. Standby available 2. Procedure for batch preparation	

TABLE 10.13 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Gas Chlorination

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Chlorine Storage and Application Room Description 1. Isolation 2. Size 3. Ventilation	Efficient Handling and Application of Chlorine. Protection of plant and plant personnel.		Adequacy	1. Storage vs use 2. Use pattern 3. Points of applic.	
			Safety	1. Ventilation 2. Isolation adeq. 3. Secure cyl. 4. Handling procedures	
Chlorinators 1. Make and applic. range	Apply chlorine to meet demand.		Adequacy	1. Chlorine resid. maintained 2. Max. demand vs avail. feed rate 3. Complaints 4. pH 5. Maintenance records	

TABLE 10.13 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Treatment

Subfunction: Gas Chlorination

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Protection	1. Cross connections	
			Continuous Service	1. Standby available 2. Cyl. change procedures	

typically include residual chlorine concentrations and pH. Records should be reviewed for these operational tests, as well as for contact time and calculations of dosage, depending upon varying quality and quantity of influent water (i.e., in instances where manual adjustments are necessary). All automatic and semiautomatic feed devices and regulators should be periodically tested, and appropriate records kept. The evaluator must ensure that required maintenance (preventive and corrective) is performed and that there are no cross-connections between treated and untreated waters.

Safety issues with respect to gas chlorination include (1) proper ventilation of storage and application areas, (2) proper isolation of cylinders within the plant, (3) physical security of cylinders, and (4) standard approved methods for handling cylinders.

These issues are summarized in tables 10.12 and 10.13.

Softening

The hardness of most water supplies is caused by the presence of calcium and magnesium ions. The anions with which these bivalent ions are associated are principally carbonates, bicarbonates and sulfates. The removal of hardness causing substances in water is not essential in order to make it safe to use. The decision usually depends on local reaction to the difficulty in making a lather with soap, on industrial and commercial usage of water, and on the cost of maintaining plumbing fixtures. Calcium and magnesium bicarbonates are designated as "carbonate hardness", and calcium and magnesium sulfates (or chlorides and nitrates) are called "noncarbonate hardness". There are two basic processes used for softening: lime-soda softening and ion-exchange.

The chemistry of the lime-soda process can be best illustrated by the following reactions.

$$CO_2 + Ca(OH)_2 = CaCO_3 \downarrow + H_2O \qquad (1)$$

$$Ca(HCO_3)_2 + Ca(OH)_2 = 2\ CaCO_3 \downarrow + 2H_2O \qquad (2)$$

$$Mg(HCO_3)_2 + Ca(OH)_2 = CaCO_3 \downarrow + MgCO_3 + 2H_2O \qquad (3)$$

$$MgCO_3 + Ca(OH)_2 = CaCO_3 \downarrow + Mg(OH)_2 \qquad (4)$$

$$MgSO_4 + Ca(OH)_2 = Mg(OH)_2 \downarrow + CaSO_4 \qquad (5)$$

$$CaSO_4 + Na_2CO_3 = CaCO_3 \downarrow + Na_2SO_4 \qquad (6)$$

Equations (2) to (4) show the removal of carbonate hardness by lime. Equations (5) and (6) show the removal of non-carbonate hardness, either originally present in the water or formed as shown in Eq (5).

From these reactions the amount of lime and soda ash required to soften a water may be calculated from the concentrations of free carbon dioxide, bicarbonate, magnesium hardness, and non-carbonate hardness. Various equations exist for the calculation of dosages. These formulas are based on pure chemical compounds. The better grades of high-calcium quicklime contain about 88 to 95 percent available CaO. High calcium hydrated lime contains about 68-70 percent CaO. Commercial soda ash contains 99 to 100 percent Na_2CO_3. The results of formulae based on pure compounds should be divided by the percent CaO in the lime to be used. For example:

To remove carbonate hardness and magnesium:

(a) lbs 100% CaO (i.e., pure compound) per million gallons =

10.6 X mg/l CO_2

+ 4.7 (x) mg/l alkalinity

+ 4.7 (x) mg/l magnesium hardness

+ (x)

Where (x) is the desired excess hydroxide alkalinity

Now: The results from (a) above should be divided by the percent CaO in the lime used and multiplied by 100.

i.e., $$\frac{\text{lb pure (100\%) CaO}}{\text{percent CaO in lime used}} \times 100 =$$

lb of "unpure" CaO to be used.

The process of lime-soda softening requires turbidity removal, i.e., coagulation-flocculation, sedimentation and filtration.

To facilitate flocculation a coagulant such as alum may be added.

When a low-magnesium hard water is treated with the amount of lime necessary to react with free CO_2 and bicarbonates, the water remains supersaturated with calcium carbonate and may have a pH of 10.4 or more.

The pH of such water should be adjusted downward before filtration. Carbon dioxide gas is therefore bubbled through the water (i.e. recarbonation) for this purpose. Carbon dioxide combines with all or a part of the unprecipitated calcium carbonate to form some soluble bicarbonate. Because of the variety of chemical reactions that may take place, it is better to make a final pH adjustment by a final recarbonization just after filtration.

The disposal of solids that result from water softening has been handled in a variety of ways; including discharge to a flowing watercourse, disposal to sludge beds or lagoons, discharge to storm or sanitary sewers, and discharge to standing water.

Lagooning of lime softening residues may be an interim or permanent solution to the disposal problem. As filling proceeds, the solids consolidate to approximately 40-50% by weight as the supernatant is withdrawn. The filled lagoon may, in some cases, be covered with topsoil and grass. A most important method of disposal of softening residues high in calcium carbonate is by recalcination for recovery of lime.

Three methods may be used for water softening by ion exchange: sodium cycle, split stream, and demineralization. The most common technique is the sodium cycle operation.

Water softening by ion exchange consists of passing hard water through the bed of an ion exchanger. There the hardness components of the water (i.e. calcium and magnesium ions) are removed from solution and replaced by sodium.

The exact mechanism of the reaction is not clearly understood. However, it is evident that the process is dependent upon adequate contact of the water with the exchange material. Adequate contact is, in turn, influenced by (1) hardness of water, (2) depth of material, (3) rate of flow, and (4) character of the exchanger. If maximum contact is to be achieved, reasonably clear water must be applied to the exchanger to prevent coating of its particles with colloidal or suspended matter.

In addition to the hardness in water, relatively small amounts of iron and manganese may be present in the bivalent form in waters high in bicarbonate. Both of these ions will be removed from solution during softening. A resin unit that is exhausted for softening will continue to remove these ions. Trace amounts of aluminum will also be removed.

Experience has shown that resins handling heavy concentrations of iron may become so contaminated that the exchange capacity for softening will be reduced far below the economic level.

When the exchanger is regenerated with salt brine, iron, manganese and aluminum will be removed from the exchange medium only slightly. The slight reduction in these materials appears to occur only at or near the surface of the exchange medium.

Evaluation Issues for Softening

Evaluation issues for lime-soda softening include those issues discussed in Module 11 (Chemical Feed and Storage), Module 14 (Waste Disposal), and in the section in this module entitled "Filtration". Additional evaluation issues include the monitoring of hardness in raw and finished waters, and those issues pertaining to the adequacy and safety of the recarbonization process. For example, in old plants, carbon dioxide gas for recarbonization was obtained by burning coke, oil or gas; in newer plants, by the underwater burning of propane and air. Adequate ventilation is an important safety parameter, especially in the older plants.

An important measure of the adequacy of the recarbonization process is the contact time. The carbonation basin should provide 15-30 minutes retention time and should be 10-15 feet deep to allow for complete absorption of the carbon dioxide. An important tool for determining the adequacy of this process and one which is useful for the evaluator is "the Marble Test". This is a rapid method for determining if a water is in balance with solid calcium carbonate.

The adequacy, continuous service and protection of the ion-exchange softening process may also be evaluated in terms of a variety of parameters. Parameters of adequacy include: the monitoring of hardness in influent and effluent waters; flow rate versus design capabilities of the exchanger; amounts of salt used versus design capabilities and removal efficiency; the frequency of regeneration compared to design estimates; the rate of backwash versus design requirements; complaints from consumers, and the stability (pH) of the finished water.

Important parameters that are useful for evaluating the potential for continuous service include maintenance (preventive and corrective) records, and on-hand salt inventories and needs for resupply under both normal and peak conditions.

As in all treatment processes, the evaluator should ensure that there are no cross-connections between treated and untreated waters, that storage of chemicals (i.e., salt) assures adequate protection from contamination, and that appropriate procedures for operation and regeneration are utilized by plant personnel.

The basic evaluation issues for both lime-soda and ion-exchange softening are summarized in Tables 10.14 and 10.15.

TABLE 10.14 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Lime-Soda Softening

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Overall System	Reduce Ca/Mg		Adequacy	Hardness Titration Raw vs Finished Hardness	
Storage and Feed 1. Alum 2. Lime 3. Soda Ash	See Module 13 Chemical Feed	and Storage			
Filters	See Section	on Filtration	Module 10.		
Sludge Disposal	See Module 14	Waste Disposal			
Recarbonation 1. Burner 2. Diffuser 3. Detention Basin	Adjust Alkalinity		Adequacy	1. Detention time 2. Degree of C. alkal. (Marble Test Results)	

TABLE 10.14 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Treatment

Subfunction: Lime-Soda Softening

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Safety	1. Ventilation of burner and system area	

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TABLE 10.15 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Ion-Exchange (Ca, Mg, Ba, Ra, Fe and Mn Removal)

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Ion Exchange Unit	Remove Certain Ions From Water		Adequacy	1. Raw vs. finished hardness 2. Flow rate vs. design 3. Salt used vs design 4. Salt use/ 1000 grains removal 5. Regeneration frequency vs design 6. Backwash rate vs design 7. Complaints 8. Stability of water (pH)	

TABLE 10.15 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Ion-Exchange (Ca, Mg, Ba, Ra, Fe and Mn Removal)

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Continuous Service	1. Maintenance records 2. Salt inventory and resupply	
			Protection	1. Cross connections 2. Procedures for zeolite regeneration in place 3. Contamination of salt storage	

CONDUCTING

SANITARY SURVEYS

OF

WATER SUPPLY SYSTEMS

MODULE NO: 11

CHEMICAL FEED AND STORAGE

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

CHEMICAL FEED AND STORAGE

PURPOSE:

The purpose of this module is to develop and discuss criteria which can be applied to the evaluation of chemical feed and storage.

OBJECTIVES:

(1) The student will be able to identify basic criteria for evaluating chemical feed and storage.

(2) The student will be able to give examples of applications of these criteria.

CONTENT:

Introduction
Some Examples
Feed Devices
Chemical Doses
Storage
Evaluation Guidelines

OTHER RELEVANT MODULES:

Module No. 10. Treatment Processes
Module No. 18. Records
Module No. 19. Maintenance

Introduction

The most careful selection and design of specific treatment processes for a particular water supply system can be made ineffective if required chemical feed and storage is handled inadequately. The evaluator must satisfy himself that both the physical and operational components of chemical feed and storage (including machinery, procedures, people and facilities) actually ensure the achievement of treatment objectives.

Some basic issues involved in the evaluation of physical and operational components of chemical feed include:

(1) timing and staging (i.e., application points) of chemical additions in treatment processes,

(2) amount of chemicals added,

(3) adjustment of amounts and timing of additions to meet changing water quality and quantities of water treated,

(4) reliability (machine and operator) of additions,

(5) recording and alarm systems to provide operational records and to alert operator of inadequate or excessive chemical feed.

Some basic issues involved in the evaluation of physical and operational components of chemical storage include:

(1) potential for contamination of stored chemicals,

(2) stability and reactivity of compounds during storage,

(3) amount of chemicals stored and available under emergency conditions,

(4) the location and availability of chemicals needed under normal and emergency conditions.

Some Examples

As discussed in Module No. 10, the removal of iron by aeration is rate-dependent on pH. Lime may have to be added in order to increase the pH and therefore facilitate the oxidation of Fe (II). There the timing and the amount required to obtain a specific pH is extremely important for successful iron removal. Similarly, it was pointed out in Module No. 10, that the amount of chlorine added in breakpoint chlorination is critical to obtaining free available chlorine residuals, and may require careful adjustment under conditions of fluctuating flow and water quality. The timely and sufficient addition of these and all other chemicals during the progress of appropriate treatment processes requires, of course, reliable mechanisms and/or operators. Reliability of feed mechanisms depends on both corrective and preventive maintenance (Module No. 19), and may ultimately depend on the availability of backup equipment. Reliability of operators depends upon proper administrative mechanisms for ensuring proper staffing, and operator recognition of required operational tasks (Module No. 18). In case of feed equipment failure or other malfunctions, and also in case of rapid fluctuations in water flow and quality, adequate operational controls ensure that appropriate adjustments and corrections in chemical feed can be made.

As indicated in Table 11.1, chemicals utilized in water treatment are extremely varied. See also Appendix 11.1 for further information. Some of these chemicals may typically be utilized in a single treatment process (e.g., ammonium silico-fluoride). Others (e.g., lime) may be utilized in a number of different treatment processes. Whether used in single or in numerous treatment processes, chemical compounds are always added for specific purposes and should therefore be known quantities. Contamination of stored chemicals and/or changes brought about because of their different stabilities and reactivities under different conditions of light, heat and moisture, therefore result in the addition of unknown or useless materials to sensitive chemical and physical reactions. Finally, adequate storage of chemicals used in the treatment of water not only depends upon protection from contamination and against destabilizing factors, but also depends on sufficiency of amount under emergency conditions, and on the ease with which chemicals can be obtained within the treatment facility.

Feed Devices

The basic issues involved in evaluating chemical feed are integrally related to the human use of specific devices. Feed devices by themselves accomplish nothing. It is the combination of man and machine that determines the adequacy of chemical feed.

Chemical feeders typically employed in treatment facilities include dry chemical feeders (both volumetric and gravimetric

COAGULANTS

Aluminum sulfate (1.0) (2.3) (bauxite)
Ferrous sulfate (1.0) (2.3)
Ferric sulfate (1.0) (2.3)
Ferric chloride (1.0) (2.3)
Sodium aluminate (1.0) (2.3)
Hydrated lime and quicklime (1.0)
Aluminum ammonium sulfate (1.0)
Aluminum potassium sulfate (1.0)

FLUORIDATION

Ammonium silicofluoride (1.0) (2.1)
Fluospar (CaF) (1.0)
Hydrofluosilicic acid (2.1) (2.2)
Sodium fluoride (1.0)
Sodium silico-fluoride (1.0)

FLUORIDE ADJUSTMENT AGENTS

Activated alumina (Beds)
"Fluo-Carb" (1.0)
"Fluorex" (1.0)
Ion-exchange resins (Beds)
Magnesium oxide (1.0)

COAGULANT AIDS

Bentonite (1.0)
Calcium carbonate (1.0)
Carbon dioxide (3.2)
Sodium silicate (2.4)

DISINFECTION

Ammonia, anhydrous (3.1)
Ammonium hydroxide (2.0)
Ammonium sulfate (1.0)
Chlorine (3.1)
Chlorine dioxide (sodium chlorite) (3.1)
Chlorinated lime (1.0)
Hypochlorites (calcium, lithium, and sodium) (2.4)
Ozone (3.3)

DECHLORINATING AGENTS

Activated carbon (Beds)
Aluminum ammonium sulfate (1.0)
Ion-exchange resins (Beds)
Sodium bisulfite (sodium pyrosulfite) (1.0)
Sodium sulfite (1.0)
Sulfur dioxide (3.1)

KEY:
1.0 Dry Chemical Feeder
    1.1 Volumetric
    1.2 Gravimetric
2.0 Solution Feeder
    2.1 Diaphram
    2.2 Piston Pump
    2.3 Rotating Cup
    2.4 Proportioning Pump
3.0 Gas Feeder
    3.1 Rotameter Solution Injection
    3.2 Diffuser
    3.3 Baffled Mixing Chamber

Table 11.1 Chemicals Commonly Used in Water Treatment (Adapted from: American Water Works Association. 1971. Water Quality and Treatment. 3rd Edition. AWWA, Denver, Colorado).

TASTES AND ODORS

Activated Carbon, powdered and granulated (Slurry or Beds)
Bentonite (1.0)
Chlorine (3.1)
Chlorine dioxide (3.1)
Ozone (3.3)
Potassium permanganate (1.0)

MINERAL OXIDATION (IRON AND MANGANESE)

Chlorine (3.1)
Chlorine dioxide (3.1)
Ozone (3.3)
Potassium permanganate (1.0)

STABILIZATION AND CORROSION CONTROL

Quicklime and hydrated lime (see "Softening") (1.0)
Sodium carbonate (see "Softening") (1.0)
Sodium hexa-metaphosphate (2.0)
Sodium hydroxide (2.0)

HYDROGEN ION (pH) ADJUSTMENT

Calcium carbonate (see "Coagulant Aids") (1.0)
Carbon dioxide (3.2) (see "Softening")
Hydrochloric acid (2.0)
Lime (quicklime and hydrated lime) see "Softening" (1.0)
Sodium carbonate (See "Softening") (1.0)
Sodium hydroxide (2.0)
Sulfuric acid (2.0)

SOFTENING

Carbon dioxide (3.2)
Ion-exchange resins (Beds)
Quicklime and hydrated lime (1.0)
Sodium carbonate (soda ash)
Sulfuric acid (see pH-adjustment section) (2.0)

KEY:
- 1.0 Dry Chemical Feeder
  - 1.1 Volumetric
  - 1.2 Gravimetric
- 2.0 Solution Feeder
  - 2.1 Diaphram
  - 2.2 Piston Pump
  - 2.3 Rotating Cup
  - 2.4 Proportioning Pump
- 3.0 Gas Feeder
  - 3.1 Rotameter Solution Injection
  - 3.2 Diffuser
  - 3.3 Baffled Mixing Chamber

Table 11.1 (Cont.) Chemicals Commonly Used in Water Treatment (Adapted from: American Water Works Association. 1971. Water Quality and Treatment. 3rd Edition. AWWA, Denver, Colorado).

systems), solution feeders, (diaphram, piston pump, rotating cup, rotary pump), and gas feeders (rotameter solution injection). Table 11.1 shows the type of feed device that is commonly used for each chemical. In some cases several types of devices are commonly used. Figure 11.1 provides a schematic drawing of both the volumetric and gravimetric feed devices.

Each type of these feeders and each adaptation of each type, has advantages and disadvantages. Volumetric dry feeders deliver a measured volume of dry chemical within a given time interval while gravimetric feeders deliver a measured weight within a given time. Volumetric dry feeders are simpler and of less expensive construction than gravimetric feeders but they are also less accurate. Gravimetric feeders are more readily adapted for recording the quantity of chemicals fed and for automatic control.

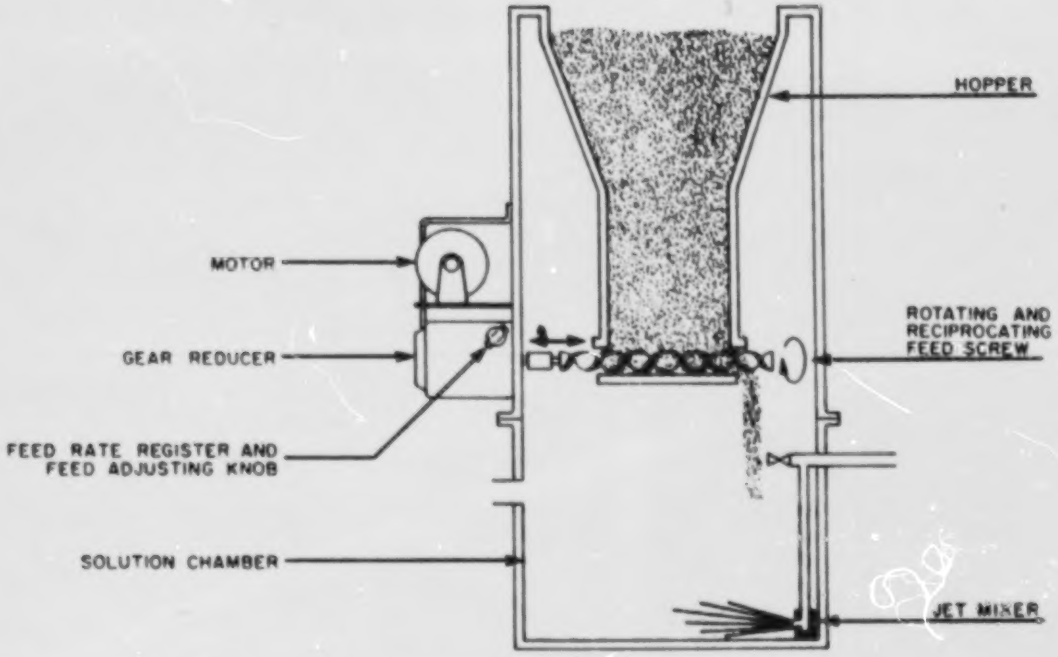
Volumetric dry feeders are available in a wide range of sizes and in several types, distinguished by the means used for measuring and delivering the chemical. Among these are the rotating rollers, rotating disc, reciprocating screw, star wheel, moving belt, vibratory pan, and oscillating hopper.

There are two general types of gravimetric dry feeders - those based on loss-in-weight of the feeder hopper and those which are based on the weight of material on a section of a moving belt. The extreme accuracy of these feeders is based on the fact that material density or consistency has no effect on the feed rate.

The choice between a volumetric or gravimetric feeder is based largely on size and economics. The gravimetrics are more expensive but have greater capacity and are more accurate. The selection of one of the types of volumetric feeders involves size, cost, accuracy and personal preference.

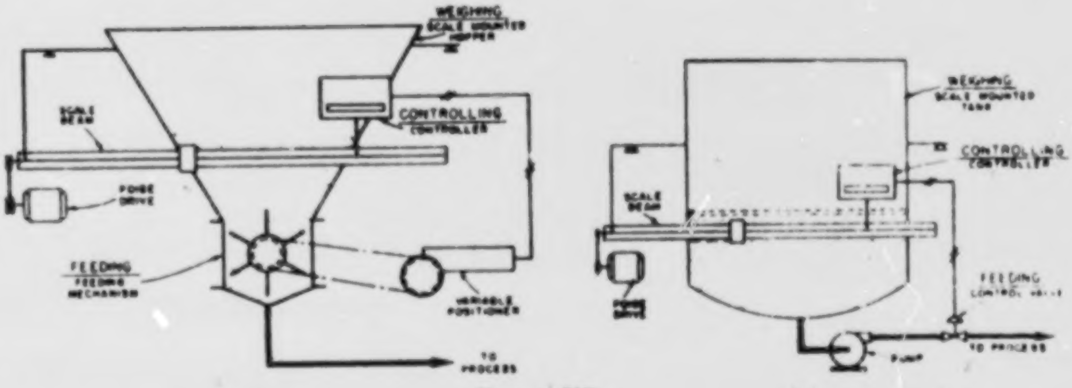
Dry feeders do not handle all chemicals with equal ease. Material which is too fine will flow like a liquid through the measuring mechanism - "flooding". Some materials will form an arch in the hopper and when the arch collapses, emit a cloud of dust and then flood the feeder. Other chemicals, either hydroscopic by nature or produced with significant moisture content, tend to form lumps which will affect the feed rate or will not be fed at all.

The measuring function of a solution feeder is accomplished by the automatic filling of a space in the feeder head with the liquid and then discharging it on each cycle. This space can be in


HOPPER
MOTOR
GEAR REDUCER
ROTATING AND RECIPROCATING FEED SCREW
FEED RATE REGISTER AND FEED ADJUSTING KNOB
SOLUTION CHAMBER
JET MIXER

Courtesy Wallace & Tiernan Division of Penn-Walt Corp.

VOLUMETRIC FEEDER


WEIGHING
SCALE MOUNTED HOPPER
CONTROLLING
CONTROLLER
SCALE BEAM
POISE DRIVE
FEEDING
FEEDING MECHANISM
VARIABLE POSITIONER
TO PROCESS
WEIGHING
SCALE MOUNTED TANK
CONTROLLING
CONTROLLER
SCALE BEAM
POISE DRIVE
FEEDING
CONTROL VALVE
PUMP
TO PROCESS
(a)
(b)

Courtesy BIF

GRAVIMETRIC FEEDER (DRY CHEMICAL)

GRAVIMETRIC FEEDER (LIQUID CHEMICAL)

Figure 11.1 Chemical Feed Devices

a pump cylinder behind a diaphram, in a series of cups attached to a rotating wheel, or the difference level in a tank.

Important considerations for the evaluation of solution feeders are required feed rates, corrosion resistance, pressure capability, and accuracy. A point to remember is that most positive displacement feeders perform most accurately near mid-range of both stroke length and stroking frequency. At the extremely low feed rates required by small plants, the diaphram feeders are more accurate than the piston type. The diaphram feeders are ideally suited for medium pressure service up to about 125 psi. They should not be used against pressures less than about 5 psi and particularly should never be used against a vacuum. The rotating cup feeder is widely used for accurate feeding of fluoride compounds. It is not intended, however, for use against pressure.

Many chlorine feeders are manually operated, and many can be adapted to program, semiautomatic or automatic proportional control by appropriate vacuum, pneumatic or electrical linkage with flow meters. However, feeders (regardless of type) that respond only to signaled changes in flow cannot be relied upon to provide adequate chlorine residual under conditions of fluctuating chlorine demand. Maintenance of mechanical and electrical linkages, and monitoring of meter accuracy, etc. is essential for proper operation.

Chemical Doses

The following are convenient formula for computing chemical doses and the amount of chemical needed to produce a certain dose.

(1) Parts per million

$$= \frac{\text{grams of chemical}}{\text{cubic meters of water}}$$

$$= \frac{\text{pounds of chemical}}{\text{millions of pounds of water}}$$

$$= \frac{\text{pounds of chemical}}{8.34 \times \text{millions of gallons of water}}$$

$$= \frac{\text{gallons of solution} \times \frac{\%}{100} \text{ chemical in solution}}{\text{millions of gallons of water}}$$

(2) Amount of chemical per day

pounds = Desired dose (ppm) x 8.34 x millions of gallons per day grams = Desired dose (ppm)x cubic meters of water per day

$$\text{gallons of solution} = \frac{\text{Desired dose (ppm) x millions of gallons of water per day}}{\frac{\%}{100}\ \text{chemical in solution}}$$

Examples:

When 360 lbs of chemical is added to 1.8 million U.S. gal water, the dose is 360/(1.8 x 8.34) = 24.0 ppm .

A dose of 5.6 ppm for 0.82 m.g.d. requires the application of 5.6 x 8.34 x 0.82 = 38.3 lb chemical per 24 hours.

A dose of 0.8 ppm for 0.75 m.g.d. requires the application of 0.8 x 0.75/0.02 = 30.0 gal. of 2% solution.

Storage

A comprehensive evaluation of storage of chemicals encompasses all aspects of chemical handling from the time of delivery to the facility to the time of use.

For example, the evaluator should note whether, upon delivery, chemicals are immediately stored or are left on the loading dock or in other areas with no provision for their possible contamination or reaction with nearby materials. The evaluator might also note the general layout of the storage area paying particular attention to (1) environmental control of the storage area, (2) isolation of reactant chemicals, (3) appropriate signing and other labeling of stored materials and areas, and (4) possible interference of storage areas with daily routines and operations.

Methods of moving chemicals from receiving to storage areas, and from storage areas to mixers and feed-devices should also be considered for their potential effect on chemicals, personnel, and the treatment plant. The use of day-tanks minimizes chemical handling on a daily basis, and reduces the number of opportunities for contaminating or otherwise disturbing controlled storage areas. Appropriate maintenance of day-tanks to remove clogs and adhesions that build up with constant use is important for the maintenance of chemical purity and efficient operations.

The evaluator may also find it useful to compare logs (if kept) of materials withdrawn from storage, logs of actual use in treatment processes, and records of purchase orders. Such a comparison can provide important information on the control of chemical handling and storage, and on the adequacy of storage for both normal and emergency conditions.

Evaluation Guidelines

The evaluation of the chemical feed and storage operation may be broken into three areas: chemical storage; day tanks; feed devices.

In considering the long term chemical storage, the evaluator must be concerned with the adequacy of the supply, the protection of the chemical stock and lastly the protection of the treatment plant and its personnel. Control of the supply is dependent on good record keeping. The records should show how much is on hand, and at what point a new order should be placed in order to prevent running out. Protection for the chemical stock will vary with the type of material. Table 11.2 shows various criteria the evaluator may use to evaluate this aspect of storage. Finally, the evaluator should review the structural and operational aspects of the storage system. Observations of the protective clothing, the maintenance and the use of safety devices such as dust control hoods are all important to a thorough evaluation.

In evaluating the use of the day tank, the evaluator must concern himself with the quantity and quality of the solution. The total capacity of the tank and the solution remaining are information bits the operator should have. The tank should have a means to maintain uniform solution strength. The evaluator should be particularly concerned with the ability to protect the water supply from spillage from the day tank and from cross connections.

Finally, the feeder itself should be evaluated. There should be evidence that the feed rate accuracy is checked periodically. The device should be reviewed to ensure that it has sufficient capacity to meet peak water demands. Because of the importance of this device, the maintenance and the availability of a standby unit should be checked. The evaluator will also want to review the potential for cross connections and the safety measures for the operator.

TABLE 11.2 Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Chemical Feed and Storage

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Storage 1. Volume 2. Method of Transfer 3. Material of container	Hold adequate quantities of chemical to assure continuous availability of uncontaminated chemicals		Adequacy	1. 30 days of supply 2. Adequate for on-hand + order lots 3. Method to determine on hand amount 4. Tank and pipe matl. spec. to chem. stored	
			Protection	Dry Storage 1. Protection from water	

TABLE 11.2 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Treatment

Subfunction: Chemical Feed and Storage

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Storage (Cont.)			Protection (Cont.)	Wet Storage 1. Overflow and drain approp. to chemical 2. Covered 3. Protected from contamination - assure positive drainage 4. Located to prevent water contamin. from spillage 5. Drain protected against backflow	

TABLE 11.2 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Treatment

Subfunction: Chemical Feed and Storage

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Storage (Cont.)			Safety	1. Vented to outside 2. Identification of chemical stored. Dry Storage 1. Handling appro. to to housekeeping and personnel. 2. Dust control 3. Respiratory equip. Gas Storage 1. Enclosed and separated from	

TABLE 11.2 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Chemical Feed and Storage

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Storage (Cont.)			Safety (Cont.)	other operational areas 2. Cylinders restrained 3. Protected from heat and freezing 4. Ventilation to outside (1 change /min) 5. Respiratory protection equipment.	

TABLE 11.2 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: **Treatment**

Subfunction: **Chemical Feed and Storage**

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Day Tanks 1. Volume 2. Tank math 3. Location re bulk storage & feeder	To provide up to 30 hrs. of chemical avail. for immediate use when bulk storage of chemical is provided		Adequacy	1. Method to deter. amount available 2. Tank material specific to chemical 3. Uniform solution strength maintained 4. Protection from freezing 5. Maintenance	
			Protection	1. Covered 2. No danger to water supply from spillage	

TABLE 11.2 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Chemical Feed and Storage

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Day Tanks (Cont.)			Protection (Cont.)	3. Cross connection control	
			Safety	1. Vent to atmos. where necessary 2. Identification of chemical stored.	
Feeders 1. Type 2. Feed Range	Apply controlled amount of chemical		Adequacy	1. Feed rate avail. vs possible demand 2. Feed rate measure reasonably accurate & checked for	

TABLE 11.2 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: Treatment

Subfunction: Chemical Feed and Storage

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Feeders (Cont.)			Adequacy (Cont.)	accuracy. 4. Volume of water treated vs chem. used 5. Maintenance and repair records	
			Continuous Service	1. Standby unit available	
			Protection	1. Separate feeder for each chem. 2. Cross connection control	
273					274

TABLE 11.2 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Treatment

Subfunction: Chemical Feed and Storage

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Feeders (Cont.)			**Safety**	**1. Feed room vented to atmos. where appro.** **2. Dust control** **3. Respiratory and skin protection provided**	

APPENDIX 11.1

PROPERTIES OF CHEMICALS USED IN WATER TREATMENT

Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Available Forms	Weight lb/ft^3	Solubility lb/gal US	Commercial Strength	Characteristics
Activated carbon C	Aqua Nuchar, Hydrodarco Norite	bags, bulk	dry: iron, steel; wet: rubber, silicon iron, stainless steel	black granular powder	15	insoluble (suspension used)		
Alum (See Aluminum sulfate)								
Aluminum sulfate $Al_2(SO_4)_3$ $14H_2O$	alum, filter; alum, sulfate of alumina	100-200-lb bags, 300-400-lb barrels, bulk (carloads)	dry: iron, steel; solution: lead, rubber, silicon iron-asphalt	ivory-colored powder granule lump	 38-45 60-63 62-67	4.2 (60°F)	15-22% Al_2O_3	pH of 1% solution: 3.4
Ammonium aluminum sulfate $Al_2(SO_4)_3$ $(NH_4)_2$ SO_4 $24H_2O$	ammonia alum, crystal alum	bags, barrels bulk	Duriron, lead, rubber, silicon, iron, stoneware	lump nut pea powdered	64-68 62 65 60	0.3 (32°F) 8.3 (212°F)	11% Al_2O_3	pH of 1% solution: 3.5
Anhydrous ammonia NH_3	ammonia	50-,100-, 150-lb cylinders	glass, iron, Monel metal, nickel, steel	colourless gas		3.9 (32°F) 3.1 (60°F) 1.8(125°F)	99% -100% NH_3	
Aqua ammonia NH_4OH	ammonia water, ammonium hydrate, ammonium hydroxide	carboys, 750-lb drums, 8000-gal tank cars	glass, iron, Monel metal, nickel, steel	colourless liquid		completely soluble	29.4% NH_4 (26° Baumé)	

PROPERTIES OF CHEMICALS USED IN WATER TREATMENT (Cont.)

Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Available Forms	Weight lb/ft^3	Solubility lb/gal US	Commercial Strength	Characteristics
Bentonite	colloidal clay	100-lb bags	iron, steel	powder, pellet, mixed sizes	60	insoluble (colloidal sol. used)		
Calcite (see Calcium carbonate)								
Calcium carbonate $CaCO_3$	marble	bags or bulk	iron, steel	powder or mixed sizes				
Calcium hydroxide $Ca(OH)_2$	hydrated lime, slaked lime	50-lb bags, 100-lb barrels, bulk (carloads)	asphalt, cement, iron, rubber, steel	white powder: light dense	 26-48 40-70	0.014 (68°F); 0.012 (90°F)	85%-99% $Ca(OH)_2$ 63%-73% CaO	Hopper agitation required for dry-feeding of light form
Calcium hypochlorite $Ca(OCL)_2$, $4H_2O$	HTH, Perchloron, Pittchlor	5-lb cans; 100-, 300-, 800-lb drums	glass, rubber, stoneware, wood	white granule, powder	52.5		70% available Cl_2	1% - 3% available Cl_2 solution used
Calcium oxide CaO	burnt lime, chemical lime, quicklime, unslaked lime	50-lb bags, 100-lb barrels, bulk (carloads)	asphalt, cement, iron, rubber, steel	lump pebble granule	50-65 60-65 50-70	Slakes to form hydrated lime	75%-99% CaO	pH of saturated solution: 12.4; detention time, temperature and amount of water critical for efficient slaking

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PROPERTIES OF CHEMICALS USED IN WATER TREATMENT (Cont.)

Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Available Forms	Weight lb/ft^3	Solubility lb/gal US	Commercial Strength	Characteristics
Chlorinated lime $CaO.2CaOCl_2.3H_2O$	bleaching powder, chloride of lime	100-, 300-, 800-lb drums	glass, rubber, stoneware, wood	white powder	48	Clorine portion soluble	25%-37% available Cl_2	Deteriorates
Chlorine Cl_2	chlorine gas, liquid chlorine	100-,150 lb cylinders; 1-ton tanks; 16-30-ton tank cars	dry: black iron, copper, steel; wet, gas: glass, hard rubber, silver	liquefied gas under pressure	91.7	0.07 (60°F); 0.04 (100°F)	99.8% Cl_2	
Chlorine dioxide ClO_2	chlorine dioxide	Generated as used	plastic, soft rubber (avoid hard rubber)	yellow-red gas		0.02	26.3% available Cl_2	
Copper sulfate $CuSO_4.5H_2O$	blue vitriol, blue-stone	100-lb bags, 450-lb barrels, drums	asphalt, silicon iron, stainless steel	crystal lump powder	75-90 73-80 60-64	1.6(32°F); 2.2(68°F); 2.6(86°F)	99% $CuSO_4$	
Disodium phosphate $Na_2HPO_4.12H_2O$	basic sodium phosphate, DSP, secondary sodium phosphate	125-lb kegs, 200-lb bags, 325-lb barrels	cast iron, steel	crystal	60-64	0.4(32°F) 6.4(86°F)	19%-19.5% P_2O_5	Precipitates Ca, Mg; pH of 1% solution: 9.1

PROPERTIES OF CHEMICALS USED IN WATER TREATMENT (Cont.)

Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Available Forms	Weight lb/ft^3	Solubility lb/gal US	Commercial Strength	Characteristics
Ferric chloride			glass, rubber, stoneware, synthetic resines					
a) $FeCl_3$ solution	Ferrichlor, chloride of iron	5-, 13-gal carboys, trucks, tank cars		dark-brown syrupy liquid		completely soluble	35%-45% $FeCl_3$, 12%-17% Fe	
b) $FeCl_3 \cdot 6H_2O$	crystal ferric chloride	300-lb barrels		yellow-brown lump	60-64	5.0 (98°F) 4.0 (86°F)	59%-61% $FeCl_3$, 20%-21% Fe	Hygroscopic (store lumps and powder in tight containers); no dry feed; optimum pH: 4-11
c) $FeCl_3$	anhydrous ferric chloride	500-lb casks; 100-,300-, 400-lb kegs		green-black powder	85-90		98% $FeCl_3$, 34% Fe	
Ferric sulfate $Fe_2(SO_4)_3 \cdot 9H_2O$	Ferrifloc, Ferrisul	100-175 lb bags, 400-425 lb drums	ceramics, lead, plastic, rubber, 18-8 stainless steel	red-brown powder or granule	70-72	Soluble in 2-4 parts cold water	90%-94% $Fe_2(SO_4)_3$, 25%-26% Fe	Mildly hygroscopic; coagulant at pH 3.5 - 11.0
Ferrous sulfate $FeSO_4 \cdot 7H_3O$	copperas, green vitriol	bags, barrels, bulk	asphalt, concrete, lead, tin, wood	green crystal, granule, lump	63-66	4.0 (68°F)	55% $FeSO_4$, 20% Fe	Hygroscopic; cakes in storage; optimum pH: 8.5-11.0
Fluosilicic acid H_3SiF_4	fluosilicic acid	rubber-lined drums	rubber-lined steel	liquid		approx. 1.2 (68°F)	approx. 35%	

PROPERTIES OF CHEMICALS USED IN WATER TREATMENT (Cont.)

Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Available Forms	Weight lb/ft^3	Solubility lb/gal US	Commercial Strength	Characteristics
Lime (see Calcium hydroxide and Calcium oxide)								
Potassium aluminum sulfate $K_2SO_4.Al_2(SO_4)_3.\text{-}24H_2O$	potash alum	bags, barrels, bulk (carloads)	lead, lead-lined rubber, stoneware	lump granule powder	62-67 60-65 60	0.5(32°F); 1.0(68°F); 1.4(86°F)	10%-11% Al_2O_3	Low, even solubility; pH of 1% solution: 3.5
Soda ash (see Sodium carbonate)								
Sodium aluminate $Na_2O.Al_2O_3$	soda alum	100-150 lb bags, 250-440-lb drums, solution	iron, plastic, rubber, steel	white or greenish-yellow crystal liquid (27° Baumé)	50-60	3.0(68°F); 3.3(86°F)	55% Al_2O_3 35% Na_2O, 5% excess NaOH 32% $Al_2O_3Na_2O$, 10% NaOH	Hopper agitation required for dry feed
Sodium carbonate Na_2CO_3	soda ash	bags, barrels, bulk (carloads)	iron, rubber, steel	white powder: extra light light dense	 23 35 65	1.5(68°F); 2.3(86°F)	99.4% Na_2CO_3, 58% Na_2O	Hopper agitation required for dry feed of light and extra-light forms; pH of 1% solution: 11.2
Sodium chloride NaCl	common salt	bags, barrels, carloads	bronze, cement, rubber	rock fine grains	50-60 58-70	2.9(32°F); 3.0(68°-86°F)	98% NaCl	

PROPERTIES OF CHEMICALS USED IN WATER TREATMENT (Cont.)

Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Available Forms	Weight lb/ft^3	Solubility lb/gal US	Commercial Strength	Characteristics
Sodium chlorite $NaClO_2$	technical sodium chlorite	100-lb drums	metals (avoid cellulose materials)	light-orange powder, flake	70	2.0 (68°F)	82% $NaClO_2$ 30% available Cl_2	Generates ClO_2 at pH 3.0
Sodium fluoride NaF	fluoride	bags, barrels, fibre drums, kegs	iron, lead, steel	Nile blue or white powder: light dense	50 75	0.35 (most temperatures)	90%-95% NaF	pH of 4% solution: 6.6
Sodium hexametaphosphate $(NaPO_3)_6$	Calgon, glassy phosphate, vitreous phosphate	100-lb bags	hard rubber, plastic, stainless steel	crystal, flake, powder	47	1-4.2	66% P_2O_5 (unadjusted)	pH of 0.25% solution: 6.0-8.3
Sodium hydroxide NaOH	caustic soda, soda lye	100-700 lb drums; bulk (trucks, tank cars)	cast iron, rubber, steel	flake, lump, liquid		2.4(32°F); 4.4(68°F); 4.8(104°F)	98.9% NaOH, 74%-76% NaO_2	Solid hygroscopic; pH of 1% solution: 12.9
Sodium hypochlorite NaOCl	sodium hypochlorite	5-, 13-gal carboys 1300-2000-gal tank trucks	ceramic, glass, plastic, rubber	light-yellow liquid			12%-15% available Cl_2	

PROPERTIES OF CHEMICALS USED IN WATER TREATMENT (Cont.)

Chemical Name and Formula	Common or Trade Name	Shipping Containers	Suitable Handling Materials	Available Forms	Weight lb/ft^3	Solubility lb/gal US	Commercial Strength	Characteristics
Sodium silicofluoride Na_2SiF_6	sodium silicofluoride	bags, barrels, fibre drums	iron, lead, steel	Nile blue or yellowish-white powder	72	0.03 (32°F); 0.06 (72°) 0.12 (140°)	99% Na_2SiF_6	pH of 1% solution: 3.5
Sodium thiosulfate $Na_2S_2O_3 \cdot 5H_2O$	hypo	bags, barrels, drums, kegs	cast iron, low-carbon steel, stoneware	standard crystal rice fine granule	64-65 65 70 61	6.2 (32°F)	98%-99% $Na_2S_2O_3$	
Sulfur dioxide SO_2	sulfur dioxide	100-, 150-, 200-lb cylinders	dry: steel	colourless gas			100% SO_2	
Trisodium phosphate $Na_3PO_4 \cdot 12H_2O$	normal sodium phosphate, tertiary sodium phosphate, TSP	125-lb kegs 200-lb bags 325-lb barrels	cast iron, steel	crystal: coarse medium standard	 56 58 61	0.1 (32°F) 13.0 (158°F)	19% P_2O_5	pH of 1% solution: 11.9

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 12

CROSS CONNECTIONS

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

CROSS CONNECTIONS

PURPOSE:

The purpose of this module is to define cross connections, to explain cross connection hazards and significance to water supply systems, and to present means of cross connection control.

OBJECTIVES:

(1) The student will be able to define a cross connection.
(2) The student will be able to explain the hazards of cross connections.
(3) The student will be able to discuss various means of cross connection control.

CONTENT:

Introduction
Cross Connection Control
Water Treatment Plants
Causes and Effects
Evaluation Questions for the Evaluator to Consider

OTHER RELEVANT MODULES:

Module No. 10. Treatment Processes
Module No. 14. Waste Disposal
Module No. 15. Storage and Distribution

Introduction

The following are two definitions of cross connection:

"(1) A physical connection through which a supply of potable water could be contaminated or polluted.

(2) A connection between a supervised potable water supply and an unsupervised supply of unknown potability."[1]

Both definitions are applicable to water supply system evaluation. Note that both definitions infer that because of a physical connection the contents of the systems may come in contact or mix with one another with resulting contamination of the potable water supply.

Cross connections represent the greatest public health hazards inherent in a water supply system. Further, because systems are continually being installed, altered, extended or repaired and new services regularly added, cross connection control is a dynamic rather than a static problem.

Commonly cross connection contamination can occur when one or some combination of the following conditions exist:

The water supply inlet is submerged

The water supply is directly connected to a contaminated system without back flow protection

A water using fixture is directly connected to a drain

One end of a loose hose is connected to an unprotected faucet

User pressure exceeds system pressure.

Table 12.1 provides some examples of cross connections and potential control mechanisms.

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[1] AWWA, WPCF, ASCE, APHA. 1969. Glossary, Water and Wastewater Control Engineering.

TABLE 12.1 Evaluation Form for Cross Connections Including Listing of Typical Cross Connections

Location	Type of Cross Connection	Responsible Person	Identify X-Connecting Contaminant	Existing Method of Preventing Contamination	Evaluation Conclusion
Dater Plant Kyle, New York	Submerged inlet line in fluoride saturator	Supt.	Sodium Fluoride	None	Air gap recommended or vacuum breaker
A.C. Plating Work 55575 Johnson Dr. Kyle, New York Plating Dept.	Submerged inlet line in chrome plating tank	Geo. Doe Gen. Mgr.	Chromium	Vacuum Breaker	Vac. Brkr. inop. Rec. air gap,2xD fill line above tank overflow
Sewage Plant Kyle, New York	City water lubrication to sewage pump	Supt.	Sewage	Surge tank for storage of city water	Surge tank properly installed and in operation
R. Smith 111 A Street Kyle, New York	Cistern and city water in same plumbing	N/A	Untreated runoff water	None	Recommendation: double gate and double check valves. Preferably the lines be disconnected.
John Adams III Elem. School Kyle, New York	Hose in floor drain in boiler room to flush boiler chemicals away	J.J. Fish Maint. Supt.	Soda ash and unknown chemicals used to treat boiler water	None	Recommendation: non-pressure type vacuum breaker

Cross Connection Control

Devices which may be employed to provide cross connection control include:

(1) an air gap in the supply line - by far the best device provided the required minimum gap dimension is maintained

(2) vacuum breakers especially the non-pressure type

(3) reduced pressure zone backflow preventer

(4) assembly consisting of two check valves and two gate valves with test cocks between the gates and checks, provided the installation is regularly inspected.

Regulatory techniques which may be employed are:

(1) Prohibit cross connections between potable water systems and other systems unless protected by a reduced pressure zone backflow preventer

(2) Prohibit direct connections to boilers unless protected by an air gap or a reduced pressure zone backflow preventer

(3) Regulate direct connections to certain types of fixtures

(4) Regulate minimum required air gaps for water outlets

(5) Regulate vacuum breaker installation

(6) Require an air gap or an approved backflow preventer at the service connection.

Management techniques include:

(1) Regular inspection of services premises for cross connections and require elimination when found

(2) Qualified plan review of all new construction

(3) A cooperative agreement with public health and plumbing inspection authorities.

Operational techniques may consist of:

(1) A strong effort to maintain at least 20 psi system pressure at all services at all times

(2) Installation of water pressure recording devices throughout the system to locate potential trouble spots

(3) Recognition of the results of a main break, planned shutdown, fire demand or other use which might exceed the hydraulic capacity of the distribution system

(4) Established procedures for reactivating a depressurized water main.

Water Treatment Plants

Cross connection control should "begin at home" with the water treatment plant setting the example for the community. The plant should be regularly inspected the same as any other industrial or commercial premises on which would be found pumping equipment, chemical storage and handling, and liquid storage in tanks or vats.

There is ample opportunity in most treatment plants for cross connection contamination to occur through a submerged inlet. A direct water connection to a pump for the purposes of priming can constitute a cross connection. Often times the backwash drains are directly connected to a waste line. Hose connections can usually be found throughout most treatment plants.

Usually water treatment plants will contain considerable piping for various purposes. A passive cross connection control program is to color code and label all piping making sure to emphasize potable water lines. Perhaps unique to water treatment plants is the possibility of cross connection through or over a common division wall between two conduits or two basins containing water of varying quality. Vertical double division walls are recommended. Also care should be exercised not to pass nonpotable or partially treated water conduits directly above finished water conduits or basins.

Causes and Effects

Once a cross connection has been established or installed by means of physical equipment it is usually only a matter of time before backflow or back siphonage will occur. Back siphonage is caused by negative pressure in the supplying system and, usually, constitutes a low order hazard to the community system but a high order hazard to the users of a particular plumbing system and its immediate neighbors. Negative system pressure can result from insufficient hydraulic capacity and/or low supply pressure in a building plumbing system. Backflow is reversed flow due to backpressure other than siphonic action. Backflow is a high order hazard associated with water service connections to any premises on which pumps are employed for moving nonpotable or toxic liquids. The effects of backsiphonage and backflow are the spread of disease organisms or toxic materials to system users. Incidents have been well documented demonstrating the serious consequences of cross connections and show that they are common. The variety of diseases spread ranges from minor gastroenteritis to fatal amoebic dysentery and has included polio in children. Toxic substances brought into human contact by cross connections include arsenic, chromate, chlorides, antifreeze and fertilizer.

Evaluation Questions for the Evaluator to Consider

The evaluation of cross connections must focus on the control program. The evaluator may spot check the treatment plant and potential services in the distribution system, but the important evaluation consideration is the continuing program of the water supply system and the local health and plumbing authorities. The evaluator should insure that these local agencies have the power to inspect and require changes. There should be evidence of inspection of new services and continuing review of identified hazardous users. The program must show that there is a follow-up system to ensure that prevention devices are installed and are tested. The evaluator is looking for an attitude of concern for this problem and evidence that there is a dynamic program of control. Table 12.2 provides some suggested specific items which an evaluator can use in the evaluation of this aspect of a water supply system.

TABLE 12.2 Guidelines for Evaluating Public Water Supplies

Function: Control

Subfunction: Cross-Connection Control

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Cross-Connection Control Program Describe that: 1. Of Utility 2. Of Plumbing Inspection Authority 3. Of Health Dept. 4. Of Other Local Entities	Minimize the potential for backflow or back-siphonage of hazardous matl. into the public water supply system		Adequacy	1. Review authority (Bldg. or plumbing code) 2. Authority to inspect 3. Involvement of utility 4. Inspection of new services 5. Ident. of hazardous users 6. Inspection of hazardous users a) frequency b) required prevention devices	

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TABLE 12.2 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Control

Subfunction: Cross-Connection Control

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Adequacy (Cont.)	7. Inspection and testing of prevention devices 8. Follow-up for correction of inspection findings 9. Spot check by field inspection 10. Spot check of treatment plant	

CONDUCTING

SANITARY SURVEYS

OF

WATER SUPPLY SYSTEMS

MODULE NO: 13

OPERATIONAL LABORATORY TESTING

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

OPERATIONAL LABORATORY TESTING

PURPOSE:

The purpose of this module is to familiarize the student with those aspects of laboratory testing that are crucial to effective water treatment.

OBJECTIVES:

(1) The student will be able to list criteria for evaluating laboratory performance.

(2) The student will be able to identify sources of information concerning the limitations and technical details of specific methodologies.

(3) The student will be able to describe evaluation issues that apply to water testing in the distribution system as well as in the treatment system.

CONTENT:

Introduction
Sampling
Laboratory Facilities and Personnel
Laboratory Quality Control
Laboratory Methods
Control of Treatment
Special Issue: The Jar Test
Special Issue: Turbidity Testing
Special Issue: Residual Chlorine Testing
Special Issue: Bacterial Testing
Water Testing in the Distribution System
Evaluation Issues

OTHER RELEVANT MODULES:

Module No. 10.	Treatment Processes
Module No. 12.	Cross Connections
Module No. 15.	Storage and Distribution
Module No. 18.	Records

Introduction

Analyses by water supplies are made to determine compliance with standards, to control water treatment, to improve plant performance and to undertake research and development necessary to efficient plant operation. Laboratory tests to control water treatment should be carried out with the following objectives:

(1) to present evidence that each unit process has proceeded according to plan

(2) to present evidence that the water has been properly prepared for each major step in the treatment process

(3) to present evidence that the final product is clear, free from taste and odor, free from undesirable chemicals and safe for human consumption.

Special emphasis should be placed on tests that are of immediate value in assessing the final water quality and safety. The residual-chlorine and turbidity tests are in this category, but bacteria tests are not because of the time required for completion.

In this module different aspects of laboratory testing will be discussed. These will include:

(1) sampling (sample handling, containers, number and preservatives)

(2) laboratory facilities and personnel (divisions, equipment, and staff certification)

(3) laboratory quality control (reagent containers and grades, calibration curves, use of blanks and cross-checks)

(4) laboratory methods (choice of methods)

(5) special issue: the jar test

(6) special issue: turbidity testing

(7) special issue: residual chlorine testing

(8) special issue: bacterial testing

(9) water testing of the distribution system.

Sampling

It is important that care be given to the sampling techniques used. Improper sampling cannot be corrected by careful laboratory work. The sample must be representative of the water to be examined, and the concentration of the constituent of interest must remain constant until the analyses are made.

Some samples require special containers and techniques. Trace iron or manganese analyses, for example, require specially cleaned containers and acidification; samples for dissolved oxygen require special glass containers and fixing reagents; samples for phenol analysis require preservatives. Preservation methods and time limits for holding are given in Methods for Chemical Analysis of Water and Wastes prepared by the U.S. EPA. Also, Standard Methods for the Analysis of Water and Wastewater (14th Edition) should be consulted.

The number of water samples which should be examined each day depends on the quality of the raw water, the rapidity with which raw water characteristics change, the multiplicity of the processes used, and the number of unit processes involved. The number of water samples examined at each stage should be adequate to provide positive control of each unit process.

Laboratory Facilities and Personnel

A properly staffed, well-equipped laboratory is a necessary requirement for an effective control program. The size of the laboratory depends on the nature and number of processes to be controlled and to a large extent upon the size of the treatment plant. Where much analysis is done, the laboratory should be divided into sections for specific purposes, such as bacterial, chemistry and physical analysis and media and chemical preparation. In large plants, separate rooms may be allocated for each specific laboratory.

The needs of the analytical program will determine the choice of equipment. The choice between manual, semi-automatic, or automatic instrumentation will be determined by the frequency and speed of the analysis required. Available equipment ranges from simple automatic titrators to expensive optical instruments. An evaluation of the available equipment should include time and cost factors inherent in the use of the equipment.

The laboratory personnel must be qualified in the area of water-treatment plant control. The person in charge of the laboratory should be preferably a bacteriologist or chemist with experience in laboratory control of water treatment processes. Where possible the state should have a program for certification of laboratory personnel and each utility should have its analysis both in-plant control and finished water, done by certified personnel.

Laboratory Quality Control

Analytical methods may represent sound scientific principles and years of development, but the effort is wasted if they are abused. The most modern facilities and equipment do not guarantee meaningful results.

The containers used for samples and reagents must be selected with care. The choice of clear or colored storage containers, soft or borosilicate glass, plastic containers, and the types of stoppers can influence results. The cleanliness of glassware and containers is critical in water analysis. Since concentrations of some constituents may be in the micrograms-per-liter range, even slight traces of extraneous material can cause appreciable error.

Blank determinations should be run to eliminate errors traceable to reagent variations. Spot checks on the reagent water should be made and there should be occasional checks on known samples to establish relative accuracy among analysts. In-plant analyses should occasionally be confirmed by an outside laboratory.

To eliminate other sources of error, periodic checks on calibration or standardization of analytical equipment or solutions must be made. Standard curves for photometers should be checked frequently. New indicator dye lots should always be checked because batch-to-batch variations may shift calibration curves. pH meters should be calibrated frequently with standard buffer solutions. Thermometers should not be assumed to be accurate, but should be compared with one known to be accurate.

Some chemical analyses are sufficiently sensitive to detect minute traces of impurities that may be found in ordinary distilled water. The use of double or triple distilled water may be necessary. Distillation of water will not remove ammonia or carbon dioxide. Passing the water through ion-exchange columns following distillation may be necessary.

Laboratory Methods

Table 13.1 shows the treatment processes and analyses that are commonly required for each treatment process. A variety of methods are available for each determination. The choice of procedures is governed by the probable concentration, the accuracy required, the presence of interfering substances, the skill of the analyst and the equipment available. The methods employed should be chosen from those specified in Standard Methods for the Examination of Water and Wastewater, 14 Edition (1975 APHA-AWWA-WPCF).

The general categories for laboratory analyses are chemical, physical, and biological. Each category can be further subdivided into types of analyses. Biological analysis may include tests for bacteria, algae, and other organisms. Chemical analysis can be described in terms of the technique employed. Colorimetric, titrimetric, potentiometric, and atomic absorption techniques are the most common. Physical analysis include the use of nephelometric, conductimetric, and gravimetric techniques.

Each type of analysis has its own quality control issues. For example, many chemical tests involve matching colors (colorimetry) either by eye or with a photometer. Photometric instruments are much more accurate than Nessler tubes used for visual comparison. These instruments, however, are not free from limitations. A photometer is not uniformly accurate over the entire scale. The difficulties are minimized if the readings are made to fall within the range 10% to 80% transmittance by dilution or concentration of the sample. It is also necessary to prepare a reagent blank and at least one standard in the upper end of the optimum concentration range along with every group of samples. Sensitivity and accuracy must be checked frequently by analyzing standard solutions to detect electrical, mechanical, or optical problems in the instrument.

Each procedure has both general and specific quality control issues that apply to it. These types of issues are described in greater detail in Analytical Quality Control in Water and Wastewater Laboratories published by the U.S. EPA and in the first chapter of Standard Methods.

Treatment Processes	Laboratory Test
Aeration	Dissolved Oxygen Carbon Dioxide Hydrogen Sulfide
Taste and Odor Control	Threshold Odor, pH
Water Stabilization	Dissolved Oxygen, pH, Hardness, Alkalinity, Carbon Dioxide
Fluoridation	Fluoride
Iron and Manganese Removal	Iron, pH, Manganese, Dissolved Oxygen
Coagulation - Flocculation	Jar Test, pH, Turbidity, Alkalinity
Sedimentation	Turbidity Total Suspended Solids
Filtration	Turbidity, Total Suspended Solids Total Coliform, Std. Plate Count
Disinfection	Residual Chlorine, pH, Total Coliform, Standard Plate Count
Softening	Hardness, pH, Std. Plate Counts, Total Dissolved Solids, Alkalinity, Iron, Sodium

Table 13.1 Laboratory Tests Associated with Various Treatment Processes.

Control of Treatment

The records of chemical dosages employed in treatment can be used as a guide to the required doses of chemical for specific raw water conditions and may indicate inefficiencies in treatment practice. Records of chemical dosages and the parameter treated for should be made daily and should be plotted on charts in order to facilitate efficiency in usage. The dosages computed in this manner, however, should be checked by laboratory tests.

Special Issue: The Jar Test

The optimum conditions for coagulation as well as the amount of coagulant needed cannot be determined from the chemical and physical characteristics of the water, but must be determined empirically. The most widely used laboratory test for this purpose is the jar test.

The water to be tested is placed in a series (5 to 6) of jars or beakers that have a capacity of 500 to 1000 ml. Various amounts of chemicals are put into the jars and the ingredients are stirred rapidly to cause the floc to form. The stirring is then stopped and the floc is allowed to settle. The jar in which the least amount of chemical produces a good settleable floc is chosen as the one with the most economical dosage. The speed and the time of mixing may be varied for different tests in order to determine which combination of speed and time gives the best results. The supernatant can then be analyzed for a variety of parameters.

The interpretation of the results of the jar test also requires a determination of the character of the floc formed. A number of different methods can be used. These include:

(1) visual evaluation of floc size

(2) visual or photometric measurement of supernatant clarity or color

(3) time of appearance of first floc

(4) rate of settling of floc.

Special Issue: Turbidity Testing

Turbidity in waters is due to the presence of suspended matter dispersed throughout the water, resulting in a reduction of its transparency. Measurement of turbidity is a measure of opacity or light scattering by the suspended particles. Attempts to correlate turbidity with the weight concentration of suspended matter are impractical because the optical properties of particulate matter bear little direct relationship to concentration and specific gravity. Nephlometric methods for determining turbidity measure the amount of light scattered at 90° when the turbidimeter is calibrated with standard formation solutions.

Special Issue: Residual Chlorine Testing

Disinfection is the most important treatment process used in the production of potable water. The adequacy of disinfection with chlorine is based largely upon residual testing.

Chlorine is not stable in aqueous solution and the chlorine concentration, particularly of weak solutions, decreases rapidly. Exposure to sunlight causes an increase in the chlorine demand. Agitation of the sample causes a loss of free available chlorine as gaseous chlorine.

The goal of the chlorination process is the attainment of a definite residual which, after a specific contact period, is known to accomplish disinfection. Proof of bacterial destruction is the only positive way of establishing the efficiency of the disinfection process. Residual chlorine determination is the only practical way for relating control information to plant personnel within a meaningful period of time. Bacterial testing of treated water has become a method for confirming treatment efficiency and providing records to meet regulatory requirements.

Conventional methods for determining chlorine residuals are based on the oxidative power of chlorine and involve reactions with reducing agents. Four of the most common methods employed are the starch-iodide test, the basic orthotolidine test, the DPD test, and the amperometric titration test.

The starch-iodide test is based on the ability of chlorine residuals to convert iodide to free iodine. In the presence of starch, free iodine produces a blue color. The intensity of the color is apporximately proportional to the residual chlorine concentration. Quantitative measurement of the total residual chlorine is achieved by acid titration of the released iodine with a standard reducing agent. This test is not a satisfactory method of analysis when the chlorine concentration is less than 1 mg/l because the titration endpoint is difficult to detect. Its principal applications are for calibration of chlorine stock solutions and for determining chlorine residuals in excess of 0.04 mg/l.

The orthotolidine test depends on the ability of chlorine to oxidize orthotolidine to a yellow-colored compound in acid solution. The color intensity, again is approximately proportional to the amount of chlorine residual present. The concentration of total residual chlorine is determined by color comparison to standard solutions using a photometer. The test is suitable for determinations in the concentration range of 0.01 to 10 mg/l. The colormetric orthotolidine test, however, is sensitive to many interferences (turbidity, temperature variation, iron and manganese, and other materials). Because of difficulties in compensating for interferences as well as inherent limitations, the procedure has been deleted from the 14th Edition of Standard Methods.

DPD (N,N-diethyl-p-phenylenediamine) is superior to orthotolidine as an indicator for total residual chlorine determination. In addition, modifications of the procedure can be employed to measure both combined and free residual chlorine. DPD reacts instantly with free available chlorine to produce a red color. The sample is then titrated with standard ferrous ammonium sulfate solution to discharge the color. Addition of iodide catalytically causes chloroamines to produce color. A colorimetric version of the DPD method is based on the fact that the red color intensity is proportional to the amount of free available chlorine in solution. Beacuse of the color stability and the simplicity of this method, it has replaced the orthotolidine test as the field method.

The most accurate method for the determination of total residual chlorine involves the use of an amperometric titrator and specific reducing reagents. The titrator is used to determine the endpoint of a titration of the sample with a reducing agent. Current flow is proportional to the chlorine concentration and decreases as the reaction proceeds. When the reaction is complete (endpoint of titration), the current flow remains constant and will not diminish by further addition of the reducing agent. This test can also be used to differentiate between combined and free residual chlorine. Accurate determination of free residual chlorine cannot be made in the presence of chlorine dioxide nitrogen trichloride, or other halogens. The substances that interfere with the orthotolidine test do not affect amperometric titration test. This method, however, requires a greater degree of skill than those methods previously described and is unsuitable for field work.

Special Issue: Bacterial Testing

Tests for bacterial examination are based on the fact that the detection and determination of pathogenic organisms such as those that cause typhoid or cholera is very difficult. The coliform group includes Escherichia Coli, which are of intestinal origin, and also strains indiginous to the terrestrial environment.

The use of the coliform index as a measure of water quality is based on two premises:

(1) Pathogenic organisms are not more resistant than coliform to natural or artificial destructive measures.

(2) The presence of coliform organisms in water is indicative of the possible presence of fecal contamination.

The second premise is sometimes stated conversely.

Two basic tests are used for the detection and enumeration of coliform bacteria. These are the multiple-tube fermentation technique (presumptive, confirmed or completed test) and the membrane filter technique.

The multiple-tube fermentation method has resulted in the Most Probable Number (MPN) index. This method is described in detail in Standard Methods.

Increasing attention has been given in recent years to the membrane filter method, which involves direct plating and differential mediums for the detection and estimation of coliform densities. The results are considered comparable with those obtained by the multiple-tube fermentation method. Investigations into the results of this method led to its adoption as a standard method in the 11th Edition of Standard Methods.

There are limitations to the membrane filter method. Valid results will be obtained only when the limitations and specific technical details are adhered to. Some pertinent limitations and technical details of this method are:

(1) Invalid results are obtained when testing water high in turbidity.

(2) Invalid results are obtained when the plates contain a high density of background bacteria.

(3) The culture plates must not be allowed to dry out during the incubation period.

(4) The number of colonies on each culture plate should not exceed 200.

(5) All glassware and other apparatus used during the test should be sterilized by standard methods.

Water Testing in the Distribution System

Laboratory testing is an important part of the effort to control the quality of water during its conveyance from the point of treatment to the point of use. Distribution systems are unlikely to be free from bacteria and other organisms unless residual chlorine is present. Since coliform bacteria are indicators of pollutants, their presence in water is presumptive evidence of contamination. The needs for an effective monitoring program in the distribution system can be summarized as follows:

(1) to offer proof that the mains have not been contaminated by cross connections

(2) to show effective disinfection of newly laid mains

(3) to monitor seasonal variation in the chlorine demand

(4) to determine whether the system is free from aftergrowths.

Chemical water quality may also deteriorate from the effects of chemical interaction between water and pipe, cross-connections, and defects in storage facilities. Various chemical analyses may be necessary to determine the source of turbid water, colored water, or water with an unpleasant taste and odor. In addition maximum contaminant levels for certain parameters specified by the U.S. EPA must be checked annually.

Evaluation Issues

Table 13.2 provides a summary of the evaluation issues which may be considered. The basic concern is to ensure that the sampling frequency and methodology follows standard methods and that the testing methods are also in compliance with accepted procedures. The evaluator can review the equipment, the written procedures and the quality control program. He should check results and question the action taken as a result of unusual numbers. Administrative aspects of the laboratory should also be reviewed. These may include the records, the maintenance procedures and the inventories of the supplies. Lastly, disposal of the wastes from laboratory operations should be reviewed to ensure that there is no possible contact with the water.

TABLE 13.2 Guidelines for Evaluating Public Water Supplies

Function: Control

Subfunction: Laboratory Testing

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Laboratory Describe: 1. Tests run 2. Equipment for each test 3. Test area 4. Written test procedures 5. Sampling procedures 6. Quality controls 7. Certifications	Control treatment processes Determine compliance with regulations		Adequacy	1. Frequency of test 2. Use of standard methods 3. Frequency of basic calibration 4. Use of blanks and check samples 5. Test records a) anomalies b) overly consistent 6. Proper equipment per test 7. Representative samples	

TABLE 13.2 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: Control

Subfunction: Laboratory Testing

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Adequacy (Cont.)	8. Sample handling and procedures 9. Check samples run 10. Split samples and quality control measures 11. Certification	
			Continuous Service	1. Stock of reagents on hand & method of supply	
			Protection	1. Cross Connections	

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 14

WASTE DISPOSAL

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

WASTE DISPOSAL

PURPOSE:

The purpose of this module is to develop and discuss some basic guidelines for evaluating waste disposal practices in water supply systems.

OBJECTIVES:

(1) The student will be able to identify basic sources and types of wastes generated in water supply systems.
(2) The student will be able to list common disposal practices.
(3) The student will be able to identify and apply general guidelines for evaluating disposal practices.

CONTENT:

Introduction
General Disposal Practices
Some Guidelines for Evaluation
Applying the Guidelines

OTHER RELEVANT MODULES:

Module No. 12.	Cross Connections
Module No. 18.	Records

Introduction

There is a variety of wastes that is generated by the operation of a water supply system. These wastes, including solids, liquids and gases, are important for their potential to impact (1) general environmental quality in immediate and distant environs of the supply system, (2) the safety of personnel, and of the public having limited or general access to portions of the water supply system, and (3) the storage and distribution of finished waters.

Sources of potential wastes in a water supply system include the following:

- screen washing drains at water-intake structures
- cleaning of settling basins
- cleaning of flocculation basins and filters
- backwashing filters, ion-exchange beds and carbon beds
- disposal of slurries from precipitation and desalination processes
- disposal of brines or acids used to regenerate ion-exchange media
- use of chemicals and other products in non-return containers
- toilet and sink drains
- floor drains in buildings
- parking lot and outside work-area drains

Specific wastes, their sources, and potential effect on the successful operation of a water supply system will vary from system to system. The evaluator should be aware of some general considerations of waste disposal, and how these considerations can be applied for evaluation purposes in specific situations.

General Disposal Practices

Four basic disposal practices may be found in water supply systems. These practices include:

(1) Discharge into surface waters,

(2) Discharge into sewage treatment plants,

(3) Lagooning and dewatering (with subsequent land-fill disposal), and

(4) Regeneration and reclamation of wastes.

Discharge into surface water, while a common practice, is not desireable. Regulatory agencies responsible for water and environmental quality increasingly require alternative modes of waste disposal. Discharge into sewage treatment plants may be possible depending on location of the treatment plant and the water supply system, cost, and the nature of wastes. Lagooning of wastes and a variety of dewatering practices with subsequent deposition of stabilized wastes in land-fills is an effective and efficient practice. The practicality of this practice depends on the type of wastes, geographical and geological features of the area, and the location of the water supply system. The regeneration and reclamation of certain wastes is technically feasible, but is not in common use. It can be assumed that this practice will become a more important means of waste disposal in the future. Table 14.1 shows the wastes that are typical of common treatment processes and the usual means of disposal.

Some Guidelines for Evaluation

In spite of the large number of factors that influence methods of waste disposal (including legislation, technology, economics, geography, geology), the evaluator may undertake to evaluate any method of waste disposal by focusing on four basic issues:

(1) What is the specific type of waste (i.e., its chemical physical and biological properties) generated by a particular water supply system?

(2) Upon disposal, what is the stability of these wastes (i.e., their potential to produce decay-products; the persistence of decay products in the environment, etc.)?

Treatment Process	Waste	Disposal Means
Aeration	None	N/A
Taste and Odor Control	Slurries	(1) (3) (4) Incineration
Water Stabilization	None	N/A
Fluoridation	None	N/A
Iron and Manganese Removal	Red Water Sludge	(1) (3) (4)
Coagulation-Flocculation	Sludge	(1) (3) (4)
Sedimentation	Alum Sludge Polymer Sludge	(1) (3) (4)
Filtration	Backwash Water Waste Filter Sand	(1) (3) (4)
Disinfection	None	None
Softening	Brine Waste Backwash Water Lime Sludge	(1) (2) (3) (4) Brine Wells
Key: (1) (2) (3) (4) See General Disposal Practices for Meaning		

Table 14.1 Treatment Process Wastes and Their Disposal.

(3) What are the specific public health and/or safety aspects of the disposed wastes and their decay-products?

(4) What are the specific routes by which these wastes and decay products can be transmitted through the environment (including the water supply system itself).

It is important that the evaluator utilize such guidelines when performing a comprehensive evaluation of waste disposal. This requires the evaluator to consider all structural and functional components (Module No. 2) of a water supply system. For example, the evaluator should not only be concerned with wastes generated by individual treatment processes, but also with wastes generated by the maintenance and operation of collection, storage and distribution systems. It is a good rule of thumb to assume that wastes are generated wherever there is activity. It is the task of the evaluator to find out which wastes are being generated by which activity.

Applying the Guidelines

Once the evaluator has identified types of wastes that are associated with the structural and functional components of a water supply system, the evaluator should consult appropriate records (Module No. 18) and plant personnel to (1) identify procedures and materials actually utilized in the disposal of those wastes, and (2) evaluate (on the basis of standard and accepted practices) the stability of both the wastes and their decay-products. He should then methodically evaluate the possibility of transmission of wastes and decay-products through the environment and through the water supply system itself. Some basic pathways are more or less probable, depending on various local conditions, including:

(1) leaching from land-fills into recharge areas or well-fields,

(2) wind-dispersal and fallout onto surface water supplies, recharge areas, and other environmental resources,

(3) structural cross-connections in the water supply system, and

(4) flooding of waste storage and treatment areas, with subsequent contamination of storage and distribution facilities.

Finally, the evaluator should ensure that the water supply system has the appropriate permits for its waste disposal. Table 14.2 summarizes this information.

TABLE 14.2 Guidelines for Evaluating Public Water Supplies

Function: **Treatment**

Subfunction: **Waste Disposal**

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Describe Equipment or Means of Disposal	**Provide proper disposal of water supply wastes including** **1. Raw Water Transmission** **a) Screenings** **2. Sedimentation** **a) Alum sludges** **b) Polymer sludges** **3. Filtration** **a) Backwash water** **b) Waste filter sand**		**Adequacy**	**1. Disposal's effect on the environment** **2. Maintenance of disposal system (records)** **3. Status of disposal permits**	
			Continuous Service	**1. Removal of waste from the treatment plant (Buildup vs storage capacity)** **2. Flood hazard**	

TABLE 14.2 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: **Treatment**

Subfunction: **Waste Disposal**

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
	4. Softening **a) Brine wastes** **b) Backwash water** **c) Lime sludges** **5. Iron and Mang. Removal** **a) Red water** **b) Sludges** **6. Laboratory Wastes** **7. Sanitary Wastes**		**Protection**	**1. Cross connection control**	

CONDUCTING

SANITARY SURVEYS

OF

WATER SUPPLY SYSTEMS

MODULE NO: 15

STORAGE AND DISTRIBUTION

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

STORAGE AND DISTRIBUTION

PURPOSE:

The purpose of this module is to present the scope and importance of the distribution system and criteria for evaluation.

OBJECTIVES:

(1) The student will be able to list the components of the storage and distribution system and explain the hydraulics.

(2) The student should be able to list criteria for storage and distribution system evaluation.

CONTENT:

Introduction
Component Parts
Storage
Distribution System Construction Practices
Operations and Sampling
Evaluation Criteria

OTHER RELEVANT MODULES:

Module No. 8 . Pumps and Pumping
Module No. 12 .Cross Connections
Module No. 18 . Records
Module No. 19. Maintenance

Introduction

The definition of distribution system is:

> "A system of conduits and their appurtenances by which a water supply is distributed to consumers. The term applies particularly to the network or pipelines in the street in a domestic water system."[1]

A properly functioning distribution system not only delivers water to consumers but does so without impairing the basic characteristics and quality provided at the point of introduction. This premise should be valid regardless of whether the water enters the distribution system directly from the source or after treatment. Obviously, the quality of water taken from the system can be no better than the finished water at the point of production.

Ideal conditions, toward which all water supply systems can aspire, include:

(1) Stable water is provided.

(2) Biologically safe water is furnished.

(3) The distribution system is inert.

(4) The distribution system is protected positively from contamination of any sort.

(5) Adequate pressure is maintained at all times.

(6) The system will function satisfactorily in emergency situations.

(7) System appurtenances are kept in the best condition.

Component Parts

As with any system, component parts join or are connected to form a whole. The distribution system may be considered to extend from the water supply source or water treatment plant output to the service connection on the water main and to consist of:

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[1] APHA, ASCE, AWWA, WPCF. 1969. Glossary: Water and Wastewater Control Engineering.

(1) Pumping stations which deliver water into the system and maintain system pressure.

(2) Mains and valves which convey water through the system and control flow of water in the system.

(3) Tanks and reservoirs which store treated water, to maintain system pressure and satisfy peak demand.

Figure 15.1 is a schematic presentation of a distribution system showing three pressure levels. Water is conveyed from surface or ground sources to the treatment plant. After treatment water is pumped to "Low Storage" for distribution by gravity to the Low Service Area, the Intermediate Booster pump and the High Service Booster pump. Automatic controls start and stop the Intermediate Booster to maintain the Elevated Storage within certain preset maximum and minimum levels. Similarly, controls maintain Elevated Storage levels for the High Service area. An Altitude Valve prevents overflow of the Elevated Storage when pumping directly to the Booster within the High Service area or when High Service pressure exceeds that imposed by the Elevated Storage.

Storage

The storage of treated waters in storage reservoirs, ground and elevated tanks and standpipes should be conducted in such a way as to meet demand and ensure the highest sanitary quality of water. Three general issues are involved in evaluating the adequacy of storage of treated waters:

(1) storage capacity with respect to normal and emergency demands,

(2) susceptibility to pollution and to contamination by vandalism, accidents, and other sources, and

(3) ease, type and frequency of maintenance required.

The significance of each of these issues in the evaluation of a particular water supply system depends upon design, construction, and operational features of the various components of the system's storage facilities.

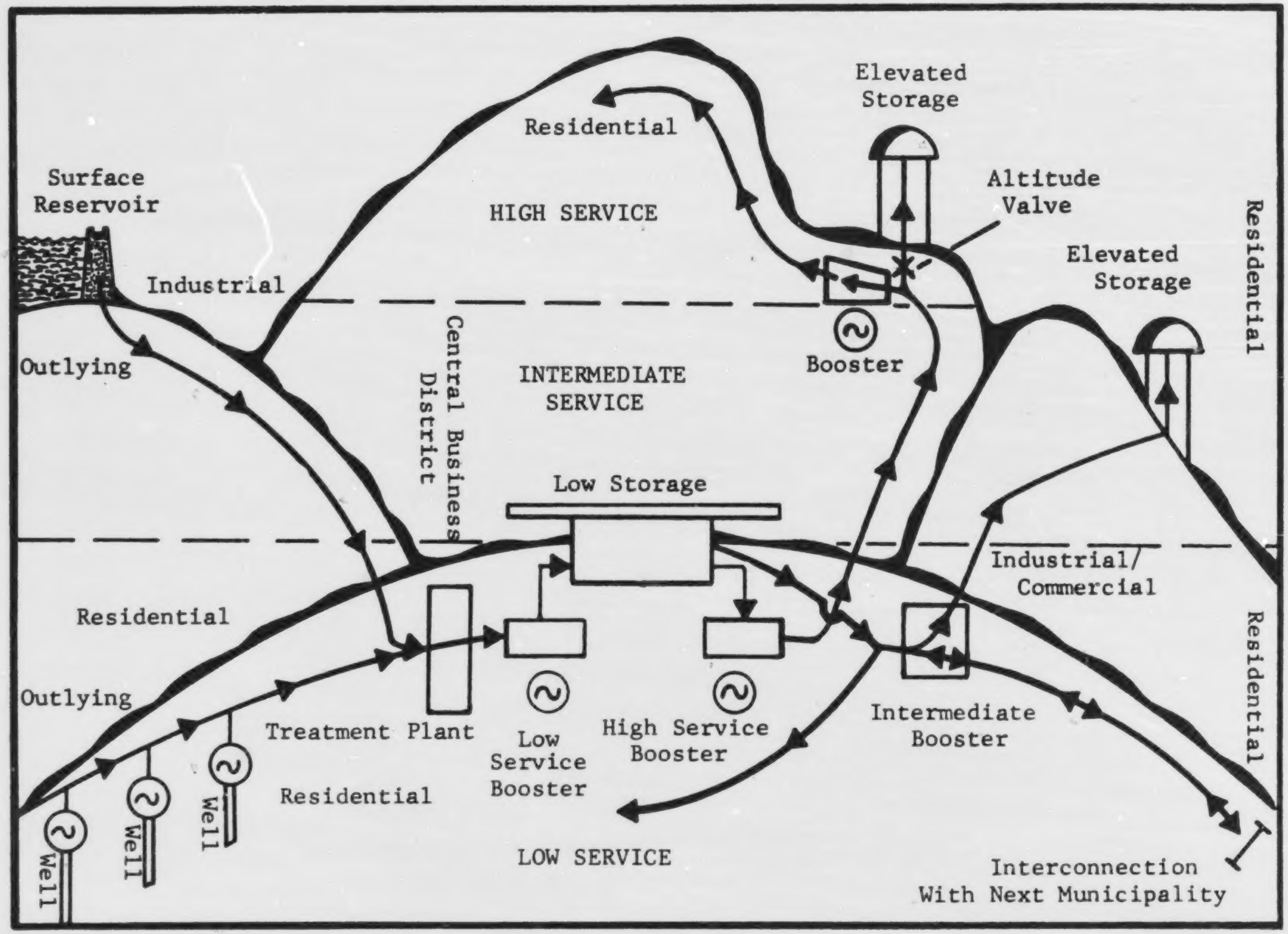
Elevated Storage
Residential
Surface Reservoir
Altitude Valve
HIGH SERVICE
Elevated Storage
Industrial
Residential
Outlying
Central Business District
INTERMEDIATE SERVICE
Booster
Low Storage
Industrial/ Commercial
Residential
Residential
Outlying
Treatment Plant
Low Service Booster
High Service Booster
Intermediate Booster
Well
Well
Well
Residential
LOW SERVICE
Interconnection With Next Municipality

Figure 15.1 Distribution System Schematic.

Structural components of storage facilities may be constructed of a variety of materials, including reinforced or pre-stressed concrete, steel, compacted earth, plastic and wood. Different facilities may include:

(1) earthen reservoirs with water-tight core walls, rip-rap inner slopes, grassed outer slopes, concrete bottom slabs, or other construction variations

(2) masonry reservoirs of varying types of construction, such as cantilever or gravity, reinforced concrete walls, and concrete slab floors

(3) elevated reservoirs with standpipe-type of steel or reinforced concrete

(4) cylindrical concrete tanks of reinforced concrete or pre-stressed concrete

(5) and a variety of elevated tanks.

The elevation of storage structures (including reservoirs and tanks) protects them from flood or highwater levels, facilitates the maintenance of water pressure, and helps to ensure that contamination from normal runoff and other sources (e.g., accidental spills) will not enter the finished water supply. In those cases where earthern, open-reservoirs are employed for the storage of treated waters (a practice which should be strongly discouraged) morphometric characteristics of the basin are extremely important. For example, the greater the surface area of the basin, the greater is the potential for nuisance plant-growth and for loss of water quality due to contamination by birds and other animals. Also, the greater the shoreline-to-surface-area ratio, and the greater the surface-area-to-volume ratio, the greater is the potential for enhanced biological activity and for various types of contamination.

A program of preventive and corrective maintenance is essential for the efficient and safe operation of a storage facility. Appropriate cleaning of storage structures, and inspection for leaks, corrosion and other malfunctions and deficiencies should be performed on a regular scheduled basis. Materials and supplies utilized for repair and needed corrections in storage facilities should be selected and utilized on the basis of standard specifications and standards. In the case of earthern storage basins, both long-term and emergency erosion control practices should be utilized, as well as suitable practices for the control of aquatic organisms. The regular and comprehensive monitoring of both water volume and water quality within selected components of a storage facility can identify problems that may otherwise be overlooked during the physical inspection of structures.

Distribution System Construction Practices

Since a water supply system is not static, but continually expanding and being upgraded, construction of new portions of the distribution system is certainly significant to a sanitary survey and to the maintenance of the functional principles discussed above. Consideration includes excavation, bedding, pipelaying and backfill. The American Water Works Association has developed standard specifications covering these activities which are, at least generally, followed in practice by consulting engineers and contractors. Standard practice calls for mains to be installed with adequate cover to prevent damage from frost or other causes, to be properly joined and bedded in granular material, and to be carefully backfilled particularly within zones immediately adjacent to the pipe. Acceptable pipe materials for distribution systems include asbestos cement, cement lined ductile iron, cement lined cast iron and, recently, PVC and fiber reinforced plastic (fiberglass). Technology has developed nearly "idiot proof" joints employing a compressed rubber ring in a groove principle and virtually eliminating from distribution system piping, poured joints and, to a lesser extent, mechanical joints.

Of greater concern today is proper testing, flushing and adequate disinfection. These activities, as with pipe installation, are the subject of standards developed by AWWA. These standards are not so easily met and usually it is a good idea for the water department to supervise these operations closely. In no case should a water line be put into service prior to a good flushing followed by disinfection and a safe water sample reported.

Especial care must be taken whenever it is necessary to place water lines close to sewer lines or to cross water and sewer lines. Reasonable standards require parallel lines to be separated by 7 to 10 feet horizontally. If the water and sewer lines intersect the water line is placed above the sewer or all portions of the sewer closer than 6 feet vertically of the water line are constructed of water service pipe for a horizontal distance of 10 feet on either side of the intersection.

Valves are an important component of a distribution system and should be installed on all branches near the main line and at regular intervals along the main, i.e., every 500 to 1000 feet. Adequate valving allows repairs and maintenance of the distribution system with a minimum of service interruption. Nearly all distribution valves are either gate valves or butterfly valves, the former commonly used for smaller sizes up to 12 inches in diameter, the latter for sizes larger than 12 inches.

Dead end water mains will cause lack of circulation within the distribution system. Where ever possible, all pipelines should be "looped", particularly new construction.

Operations and Sampling

A distribution system needs careful daily operation if the supplied water quality is to be maintained and if sufficient pressure is to be provided. Pumping stations have been covered by Module No. 8. Mains and valves, since they usually are of variable age and condition, require regular attention. Good record keeping is essential in order to be able to locate breaks to control water flow or to provide location to others to prevent damage i.e., construction including excavation near water lines. All valves in the system should be regularly, at least annually, inspected and operated. Records of these inspections should be made.

Tanks and reservoirs are subject to contamination if uncovered or if cover is poorly constructed or deteriorated. Windblown materials, under the right conditions, can enter the tank through any vents or other openings. Additionally, ground storage reservoirs are susceptible to contamination from surface runoff and underground seepage. Consequently regular and frequent sampling and inspection is advisable. Care should be taken not to draw down storage to a point of vortexing and resultant air entrainment into the system.

Booster pumping stations inherently lead to negative pipe pressure unless the pumps draw from an intervening reservoir. Blowoffs and vacuum relief valves can allow surface water contamination if adequate drainage is not provided or protection against storm water flow is omitted. Controls respond to the distribution system conditions of low water levels or low pressures and call for additional water from supply, usually by pumping.

Biological sampling of representative points throughout the distribution system is an essential program. The plan should conform to a meaningful effort to trace the course of the finished water through the system: prime conduit, major and minor arteries. Sampling should not be done merely as a matter of convenience. Considerations in developing a sampling program include:

(1) System layout

(2) Pumping stations

(3) Booster pumping and chlorination stations

(4) Storage tanks and reservoirs

(5) Random and variable locations of samples within logical plan.

Evaluation Criteria

Tables 15.1 - 15.4 list the evaluation criteria that may be applied to the storage and distribution system. The prime concern of the evaluator is to gain an overall view of the system. The key criteria are its present ability to deliver safe water in the quantity required. Once the evaluator has documented the configuration of the system he can look at the measures of operational success. These include pressure history, complaint records, fire underwriter reports, sample program and water test results. The likelihood of the distribution system continuing to be adequate will depend upon the maintenance and the continual updating of the system maps and records. The evaluator must also review the cross connection program. This review must include an assessment of how active the program is (Module 12).

After looking at the total system, the evaluator may review the component parts. The pump stations should be evaluated for capacity and performance (Module 8). The need for continuous service is obvious. Good preventive maintenance (Module 19), emergency plans (Module 21) and standby equipment are essential elements to providing the required service.

A second key component of the distribution system is the storage of treated water. The key evaluation issues for this components are the volume of storage as it realtes to average and peak uses. The amount of draw down and water level are important considerations. Protection of the supply from the elements and vandalism are also important aspects. Table 15.3 contains a detailed list of other criteria applicable to the storage component.

The third component of the distribution system is the mains and valves. Maintenance, size, standards for new installation, are important criteria for mains. It is also important that evaluator review the unaccounted for water (Module 18). The programs for protection of mains should include disinfection procedures, flushing programs, and standards for installation at or near hazardous users. The placement of valves in the system should be reviewed to ensure that there is reasonable isolation capacity. The hydrants may be best evaluated by reviewing the fire underwriter's reports.

TABLE 15.1 Guidelines for Evaluating Public Water Supplies

Function: Distribution

Subfunction: Overall System

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Overall System Map Showing 1. Pumping stations (incl. indication of pumps & controls) 2. Chlorine booster stations (capacity) 3. Storage Tanks (size, type) 4. Mains (size & matl.) 5. Valves 6. Hydrants	Continuously deliver quantities of safe quality water to users		Adequacy	1. Pressure history 2. User complaints 3. Fire underwriter reports 4. Conditions under past emergencies	
			Continuous Service	1. Maintenance records 2. Currency of system map (Date)	
			Protection	1. Bacterial sampling a) frequency b) representativeness	

TABLE 15.1 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Distribution

Subfunction: Overall System

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
7. Meters 8. Pressure recorders			Protection (Cont.)	c) bad sample followup d) sample results 2. Cross connection program (Mod. 12) 3. Chlorine residual sampling results 4. Chemical sampling results	

TABLE 15.2 Guidelines for Evaluating Public Water Supplies

Function: Distribution

Subfunction: Pump Stations

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Pump Stations Describe: 1. Pumps 2. Controls 3. Meters 4. Housing by station	To add sufficient energy to the water to force adequate water through the distribution system		Adequacy	1. Pump capacity vs use and projected use 2. Pump performance curves vs design curve	
			Continuous Service	1. Maintenance records 2. Check stand-by pump and auxilliary power under load. Utility check program 3. Excessive heat or vibration	

TABLE 15.2 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: Distribution

Subfunction: Pump Stations

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Continuous Service (Cont.)	(feel by hand) 4. Routine maintenance program	
			Protection	1. Sump pumps & gravity drains not sewer conn. (flooding) 2. Priming water cross connections 3. Leaks	

TABLE 15.3 Guidelines for Evaluating Public Water Supplies

Function: Distribution

Subfunction: Storage

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Description of each Tank	Provide reservoirs for system availability and to maintain constant pressure		Adequacy	1. Volume stored vs use and need patterns 2. Excessive drawdown 3. Water level monitoring 4. Excessive overflow	
			Protection	1. Tanks covered 2. Manholes, vents, overflows protected 3. Cross connections (overflows & drains)	

TABLE 15.3 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Distribution

Subfunction: Storage

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Protection (Cont.)	4. Flooding, positive drainage 5. Management in idle periods	
			Continuous Service	1. Maintenance records 2. Annual interior inspection	
			Safety	1. Security measures 2. Enclosed ladders	

TABLE 15.4 Guidelines for Evaluating Public Water Supplies

Function: Distribution

Subfunction: Mains and Valves

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Mains 1. Size 2. Length 3. Material	Carry water to consumers		Adequacy	1. Maintenance records 2. Size of mains adequate to service 3. Small dia. mains 4. Unaccounted for water 5. New installations & repairs	
			Protection	1. Disinfection and sampling procedures 2. Installation re: hazards & hazardous users	

TABLE 15.4 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: Distribution

Subfunction: Mains and Valves

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Protection (Cont.)	3. Flushing program	
Valves and Hydrants	Control of Water Flow and Fire Protection		Adequacy	1. Isolation capability 2. Fire underwriter's report	
			Protection	1. Hydrant drains used 2. Disinfecting and sampling procedure 3. No hydrants on <6" pipe	

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 16

MANAGEMENT

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

MANAGEMENT

PURPOSE:

Management is responsible for putting together all of the components of a system and the operation of the system to meet the objectives. The purpose of this module is to look at some means of evaluating the management.

OBJECTIVES:

(1) The student will be able to describe important components of management.
(2) The student will be to identify management practices that are generally associated with good management.

CONTENT:

Introduction
Ownership and Control
Management Functions and Principals
Some Management Tools
Conclusions

OTHER RELEVANT MODULES:

All Modules

Introduction

Although we spend much of the time evaluating other parts of the system, it is management that determines the success or failure of the water supply operation. Management determines what facilities there should be, how they should be set-up and how they will be operated. Management policies and procedures or the absence of them are key determinants in the success of the system.

Management of a water supply system may be considered successful if the system is able to provide water in the quantity and quality required by the community at a revenue that exceeds the operating expenses and provides for the replacement of the facilities. Other constraints are also important. The unit price must be fair to all customers. The treatment of employees must conform to laws as well as be conducive to good job performance. Many other constraints may also be imposed in a definition of an adequate water supply system. However, many of these criteria are subjective and difficult to measure. It is also very difficult to integrate all of the evaluation criteria into a single index of the water supply system quality and its management.

Management scientists have not isolated any single approach which necessarily ensures the success of an organization. They have found that certain principles are associated with successful organizations. They have also found that certain tools are useful and often used by successful organizations. If the evaluator is familiar with these principles and tools, he is then able to evaluate management in two areas:

(1) the overall results of the operation as manifested in the financial figures, the conformance to health standards, etc.

(2) the approach used by management to achieve the results.

In most cases, a system that is inadequate in the results achieved probably has a management that is not using the management principles and tools that are available. While the use of these does not ensure success, they should assist management to focus on the problems.

The system personnel can be very sensitive and defensive about the results of an evaluation. When the evaluation directly approaches the management practices, the problem becomes more acute. Management may perceive it has a direct attack on their capabilities. Poor handling of this area of evaluation may also jeopardize progress in other important areas of the water supply program.

Ownership and Control

The management of a water supply system is strongly influenced by the differences between public and private ownership. Approximately 70% of the systems are owned publicly. The voter or property owner is the ultimate system owner. He is, of course, the user also. The water supply system is a local monopoly. As such, it is regulated by governments at all levels. At the local level, it may be part and parcel of the government or it may be recognizable as a separate entity. The state government imposes controls on health standards, financing, rates, etc. The Federal government has also imposed controls when interstate commerce is affected or the state government has not fully taken responsibility.

Because of the type of ownership, the water supply system manager is subject to requirements that are different from the manager of a private enterprise. There is only one product; it is taken for granted until it is not available; its availability is almost a "right". Users measure, therefore, the success in terms of reaction time to service demands. Pressure on this aspect is often increased by the political nature of the control. The ownership is widespread and distributed equally. It is represented by a few. As a result, the manager is faced with reaction to political demands as well as those for the most efficient operation. Since the users and the owners are the same group, their objectives are the same and are usually short-term. Minimum costs and rates are emphasized at the expense of longer term replacement of capital items. Management policies may need to reflect these considerations.

Management Functions and Principles

The responsibilities of management are clear. Each person in a supervisory position, whether it is a crew leader or the general manager performs the same functions. Each must plan what is to be done; organize the human resources in such a way that the plans can be executed; provide the people to perform the activities; direct the personnel to accomplish the tasks; and lastly, control or ensure that the job has been accomplished. This is a continuous process. See Figure 16.1 . The process is necessary regardless of the size of the water supply system. Size only determines how far the work must be divided to be accomplished.

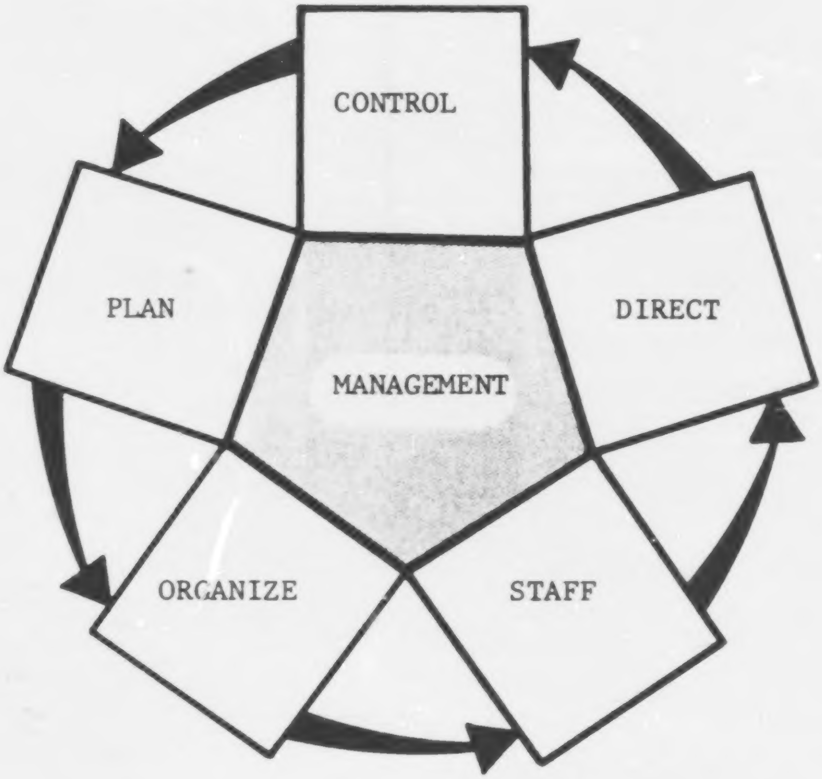
CONTROL
PLAN
DIRECT
MANAGEMENT
ORGANIZE
STAFF

Figure 16.1 Management: A Continuous Process.

Planning consists of selecting appropriate objectives, and the development of policies, programs and procedures necessary for the achievement of the objectives. Throughout an organization there must be a clear understanding of the total organizational objective and how each unit of the organization contributes to that objective. The hierarchy of objectives will dictate the policies and procedures that are appropriate to the sub-units. Planning is always concerned with the future. It may be planning the next day's work for the maintenance crew or it may involve the planning of financing for future capital expenditures one year hence.

Organizing consists of taking the plans and breaking them down into activities that can be grouped. It answers the question of who is going to do what. Its output sometimes is an organization chart and sometimes it is a list of who will do what job tomorrow.

Staffing is providing the people to perform the activities. This may involve short range decisions such as who to assign to which work crew or it may involve longer range commitments such as the hiring of an engineer to assist in the system operation. The output of this function is such things as personnel schedules.

Direction is the day to day supervision of the people and activities. It may be evident in very formal ways such as daily or weekly staff meetings or direct on-the-site supervision of construction or maintenance crews. It may be very informal and not apparent especially at the higher levels of management.

Control is the last and most important function of the manager. He must devise means by which he can measure progress against the objectives. Such measures may include such things as budgets, number of manhours to do a job, number of billing errors, number of downtime hours, quality of product, etc. Plans are used to develop what goals may be reasonably set. Control is the process of measuring the results and taking action to bring the results up to expected performance. Control starts the cycle of planning again. Controls are evident in a myriad of possible performance standards that management may use.

All supervisors, managers and even one-man water supply systems must perform the above five basic functions. As soon as the system requires more than one person, problems of organization of people arise. From the study of successful organizations, some general principles have been isolated. These principles are all related to the organization of a group with a common set of objectives. Adherence to or disregard of these principles does not ensure success or failure. However, most organizations operate more efficiently when they are run in accordance with the principles.

An organization should have a clear line of authority from top to bottom. The chain of command should be evident from the organizational structure. No individual should have more than one "boss". Each individual should know from whom he takes orders. The direct authority or "line" organization must exist on paper as well as in fact.

The activities of the organization should be broken down into logical units. These might be broken down geographically or functionally or by other means. As soon as activities are isolated for specialized organization, a balance must be struck. A supervisor can only supervise a limited number of people. Too many results in the supervisor being unable to perform all of his functions well. If he is asked to supervise too few, there will be extra layers of management and too much review of subordinate decisions. As soon as an activity is broken out for separate organization, the manager must delegate his authority to his subordinate so that the subordinate may perform the task. Decisions should be made at the lowest possible level of the organization to prevent bottlenecks. Although a manager may delegate his authority, he may never delegate his responsibility to perform the job. Lastly, the manager cannot hold a subordinate responsible for a job over which he does not have full authority.

In a brief evaluation of a water supply system, it is difficult to establish how the management is performing against these criteria. The evaluator can only look at some of the more visible indicators of the management approach. The water supply system should have an organization chart that is up to date. Review of this and the general knowledge of the size of the organization may show potential organizational problem areas. These may be pursued by asking questions of the supervisors and operators. The informal organization is as important as the formal one shown on the chart. A question such as "Who's your boss" to a plant operator may be revealing.

The amount of time spent on the evaluation of management depends upon the policies of the evaluating agency. Should a quick overview be sufficient, there are several other key management tools for which the evaluator may look. Job descriptions which clearly define responsibility and authority are useful. Monthly profit and loss statements are important to financial success. These may be reviewed for trends in revenue and expenses. The use of departmental budgets is a method of tracking progress against the annual plan. The existence and use of these management tools shows that management is alert to some of the most important controls. We will look at these tools and others in more detail in the next section.

Some Management Tools

The use of management tools requires judgement. It is not true that more use of tools necessarily leads to better management. In fact, the use of too many tools may hinder efficiency. It takes time to generate and organize the data to be used for control. It also takes time for the manager to administer the system and review the materials. The benefits must clearly outweigh the costs. What is important for some organizations may not be for others. As an example, an elaborate perpetual inventory control system is not necessary for a small water supply system, but it may be important to a large one due to the length of time needed to process requisitions. A visual bin system may provide all the control needed for a small system.

As the evaluator visits each of the areas during the field survey, he may evaluate how the department is managed by asking a few questions. These questions should be directed at how the supervisor plans and schedules the work for the department and what sort of controls he uses to measure the output or progress against the plans. As an example he may ask if the billing department has a schedule for sending out bills. Does the department measure number of invoices sent out per day? Are they on schedule?

In some cases the management may be able to set some form of work standards against which the progress can be measured. These may range from very sophisticated work measurement devices to a simple judgement of what to expect from a subordinate. Although a formal program may not exist, every supervisor must form an idea of reasonable workloads in order to staff his area. Better programs include method improvement and work measurement based upon time and motion study. Even management can be measured through a program of management by objectives. A supervisor and his superior will agree on the objectives for the year. The supervisor can be rated on his success against those objectives.

Another management tool is the inventory control system. All water supply systems will need inventory controls on supplies and maintenance items. The degree of control will depend upon the size of the water supply and the value of the inventory. As the value of an item increases, closer controls should be kept on it. In such key areas as maintenance and treatment, an evaluator may ask questions about how they know when to re-order and how often they run out of the item. Both frequent and zero stock-outs are indicators of lack of control. The latter probably indicates too large an inventory which is very costly in dollars and space.

Closely allied with inventory control are purchasing procedures. Control without excessive delays is desired. A system or procedure that ensures approvals at levels appropriate to the amount of expenditure is one method of ensuring proper control, yet prevents excessive approvals on small items. Budget controls provide another means of keeping a check on purchases. Splitting of the requisitioning, approval, receiving and payment functions provide security.

The use of an operating budget is the most important tool. It should consist of an overall financial plan for the water supply system. This plan will be the sum of all of the plans for each department. Each department must estimate its costs by category for the year. These figures can then be compared with the expected revenues. This may result in budget cutting to meet revenues. After the recycling is complete, the system and its parts will each have a budget against which actual operating costs may be measured. Each supervisor may be held accountable for the achievement of that level of costs. To ensure accountability, his budget should include only those costs over which he has control. Along with an operating budget, another useful device is the capital budget. This helps the water supply system to determine what it needs for capital funds for the next year and over the next five years.

Conclusions

We have stated that there is no one way to manage a water supply system. The best measure of management may be the results. The other parts of the sanitary survey measure the results of management actions. The profit and loss statement also measures the short-term success. However, this may be deceiving if items such as maintenance are being deferred. Besides the measurement of results, management can also be evaluated on the tools it uses. A number of these have become generally accepted. However, their use must be tailored to each organization. The evaluator must recognize that flexibility is needed. Table 16.1 summarizes some evaluation criteria.

TABLE 16.1 Guidelines for Evaluating Public Water Supplies

Function: Control

Subfunction: Management

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Obtain Organization Chart	Describe the organization used to assign responsibility for developing, operating and maintaining all aspects of water utility		Adequacy	1. Responsible off. for each function 2. Future plan available 3. Management control provided 4. Implementation of plan 5. Records and reports used by manager 6. Communication of problems to upper management 7. Is revenue adequate	

TABLE 16.1 Guidelines for Evaluating Public Water Supplies

Function: Control

Subfunction: Management

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Adequacy (Cont.)	8. Complaint records 9. Too many or too few reporting increments	

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 17

STAFFING

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

STAFFING

PURPOSE:

The skills required and the number of people needed with that skill are key decisions that affect all operational areas of the water supply system. This session will help the evaluator look at this aspect.

OBJECTIVES:

(1) The student will be able to list several areas of personnel management which he can evaluate.

(2) The student will be able to identify means by which he can acquire the information needed for evaluation.

CONTENT:

Introduction
Personnel Management Programs
Classification, Certification and Training
How Many
The Effects of the New Interim Primary Drinking Water Regulations

OTHER RELEVANT MODULES:

Module No. 16. Management

Introduction

As pointed out in our discussion of management, staffing is an important function of management. Staffing is concerned with the type and number of personnel needed to perform the functions and activities in the organization. The mix of skills needed for the operation of a water supply system is unique to the industry. While some skills, such as a construction laborer, are common to many industries, certain engineering, laboratory and treatment process operational skills are not found in the general labor market. An additional problem is the need to combine these skill requirements into one or very few employees. Table 17.1 highlights this problem. Of the 40,000 community water supplies in the U.S., 91.2% produce one million gallons per day or less. These 36,506 systems produce only 11.2% of the total U.S. daily production. These figures show the importance of the small supply system in terms of numbers. Since the small system can not afford to hire specialists in all areas, most of the systems are forced to rely on personnel who can perform several different functions. The criteria for evaluation of staffing aspects must be modified to fit these economic realities.

Personnel Management Programs

Regardless of the size of the water supply system, the system must manage its personnel in such a way that it can acquire and retain competent personnel suitable to the job requirements. The cost of people is the largest single operating cost for a system. These employees are a resource just as the water supply or the treatment facility, etc. Efficient use of all resources is a prime responsibility of management. Efficient use of people depends heavily upon motivation. Good personnel management programs can help achieve the right motivation.

The evaluator may not be able to determine precisely how well the human resource is being utilized or be capable of discussing the subject, but he should be aware of the tools and procedures that are generally accepted as being associated with good personnel management. Three areas are probably the most important. These are compensation, communication and performance review.

The compensation for individual employees must be based upon a consistent and fair plan. A job evaluation program that relates jobs within the system in terms of complexity, responsibility,

PRODUCTION CATEGORY (Millions of Gallons Per Day)	COMMUNITY SYSTEMS		PRODUCTION	
	NUMBER	% OF TOTAL	MILLIONS OF GALLONS PER DAY	% OF TOTAL
.01	8,875	22.2	43	0.1
.01-0.1	18,331	45.8	624	2.0
0.1-1.0	9,300	23.2	2,957	9.1
1.0-10.0	3,036	7.6	8,608	27.0
10.0-30.0	325	0.8	5,477	17.2
30.0-50.0	69	0.2	2,232	7.0
50.0+	64	0.2	11,958	37.6
TOTAL	40,000	100.0	31,899	100.0

Table 17.1 Number of Community Water Supply Systems and Daily Production for Seven Production Categories. (Adapted from: Energy Resources Co., Inc. 1975. Economic Evaluation of the Promulgated Interim Primary Drinking Water Regulations. U. S. Environmental Protection Agency. Office of Water Supply, Washington, D.C.)

skill requirements, etc. is an essential part of the plan. The internal pay scale should also be related to the wage rates for similar jobs found in the community. Actual wage rates paid to an individual should reflect individual performance. There should be a program of regular review of each employee's salary. Lastly, the fringe benefit program must be realistic and competitive.

The second area is communication within the organization. Employees want to know what the policies and procedures are. They want to know about the whole organization and its direction. At the same time they want the opportunity to discuss grievances, make suggestions and generally inform management of their viewpoint. Both formal and informal channels of communication may be used.

The third area of good personnel management is that of performance review. All employees want to know about their performance. Part of this evaluation is done through good supervisory technique. Part of it should be formalized into a regular review program of each employee. Good job descriptions are critical to the success of this program.

Classification, Certification and Training

The water supply industry has not yet enjoyed universal acceptance of a job classification and operator certification program. Job classification has been hampered because of the diversity of duties that individuals are responsible for in the smaller (and more numerous) water systems. The lack of uniformity in duties has made it difficult to develop national standard certification procedures. Over half of the states have developed formal mandatory certification programs. The student should make sure that he is familiar with the program, if any, for his state. Part of the review of each system may include the number of personnel who are certified and at what level. To make the evaluation meaningful, the evaluator will have to determine the number of certified personnel actually required for a given system under state regulations. This will depend upon the job descriptions and number of people in those jobs.

Training of personnel is another important area of staffing. The sources of information for this may be twofold: personnel records, and individual employees. An inspection of personnel records will provide (if they are accessible and well kept) a complete compendium of formal training. The evaluator should relate this training to the skills required for the job. Discussions with the personnel during the field survey can also help to determine if there has been sufficient cross training among personnel to provide back-up. This is essentially on-the-job training and is probably not formalized. Its importance is obvious to the continuity of water supply, especially in the small systems.

How Many

The Oklahoma Foundation for Research and Development Utiliation, Inc. completed a study in 1974 which was aimed at establishing the number of personnel required to operate a water supply system.[1] The basis of the study was existing supplies. No one factor could be found to use as a good means of estimating the number of operators needed. Figure 17.1 shows the factors that seem to influence the existing staffing levels. Because of individual differences between systems, it is difficult to use such an approach for evaluating staffing levels at a particular water supply system. A better method is through work measurement (See Module No. 16) which will determine what staff level is appropriate to the workload of that facility. The staff level determined by such a study may then be altered to fit management policies and problems. For example, if a number of personnel are approaching retirement, extra personnel may be needed as trainees. Or, if the utility wishes to provide employment for the handicapped, some adjustment in staffing may be necessary. The evaluator's role in determining the quantity of the staff is best limited to the review of the management technique used and management's awareness of special problems such as age of the staff.

The Effects of the New Interim Primary Drinking Water Regulations

One of the evaluator's roles is to disseminate information to the water supply systems. The new drinking water regulations will have substantial effect on many areas of the water supply. Staffing will be one of those areas affected. There are currently about 180,000 people employed in the industry.[2] These regulations will add between 13,000 and 27,000 additional operating jobs. These will fall mainly in the water quality analysis and treatment

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[1] Oklahoma Foundation for Research and Development Utilization, Inc. 1974. Development of Manpower Planning Criteria for Water Supply Systems. Oklahoma City, Oklahoma.

[2] Energy Resources Co., Inc. 1975. Economic Evaluation of the Promulgated Interim Primary Drinking Water Regulations. U.S. Environmental Protection Agency, Office of Water Supply, Washington, D.C.

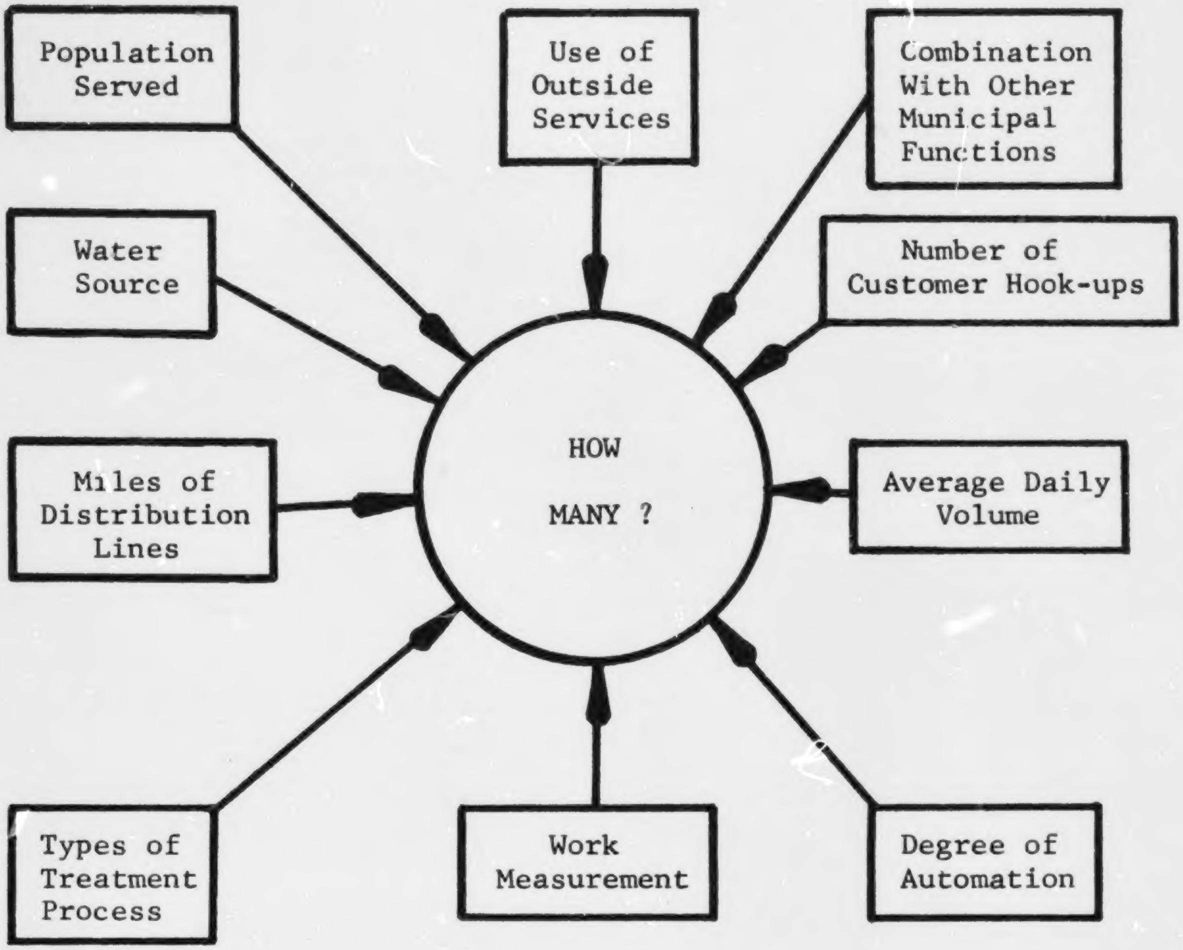

Population Served
Use of Outside Services
Combination With Other Municipal Functions
Water Source
Number of Customer Hook-ups
Miles of Distribution Lines
HOW MANY ?
Average Daily Volume
Types of Treatment Process
Work Measurement
Degree of Automation

Figure 17.1 Factors Influencing the Number of Employees Needed for a Water Supply System.

operator categories. Alert water supply system management must look ahead to determine how they will acquire the added skills and/or personnel that will be needed.

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 18

RECORDS

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

RECORDS

PURPOSE:
The purpose of this module is to demonstrate both general and specific uses of water supply system records by the evaluator.

OBJECTIVES:
(1) The student will be able to identify types of water supply system records.
(2) The student will be able to give examples of the information contained in different types of records.
(3) The student will be able to give examples of how he can use this information in his evaluation of a water supply system.

CONTENT:
Introduction
Comprehensive Overview
Specific Issues
Follow-Up
Summary
Criteria for Evaluating Records

OTHER RELEVANT MODULES:
All Other Modules.

Introduction

One of the basic sources of information on the structural and functional components (Module No. 1) of a water supply system is the set of records maintained by the facility. These records are of various types and, depending on the particular facility, may include different accounting, equipment, injury and accident, office, personnel, maintenance, and laboratory reports. Data and information contained in such reports have several important uses for the evaluator, including the following:

(1) The evaluator can quickly achieve a comprehensive overview of a water supply system with which he is unfamiliar.

(2) Depending upon the types of records available to him, the evaluator can also quickly identify specific issues that will require his attention during the field survey.

(3) Both administrative and operational reports may be used by the evaluator to confirm and/or double-check impressions and information he may already have received during his survey of the physical plant and conversations with personnel.

Of course, it is also possible that the evaluator can find himself so overwhelmed by minutiae contained in many types of records that he may fail to extract precisely the kind of information he requires for his evaluation. It is therefore important that the evaluator keep clearly in mind the following questions:

- What type of record is relevant to what evaluation issue?
- Specifically what information in each type of record is directly relevant?
- What additional and related information and/or follow-up may be required?

Comprehensive Overview

A variety of records may provide a rapid means for identifying the specific components of a particular water supply system with which an evaluator is unfamiliar. For example, if a "vulnerability analysis" has been performed at a facility as part of an emergency planning study, records of that study may include information similar to that included in Table 18.1, which denotes interrelationships among components of a particular ground-water supply system. Such a table rapidly provides the evaluator with an overview of just what is structurally present in that supply system, and how and why the components are interrelated. While the primary purpose of this type of table is directly related to emergency planning, the evaluator may nevertheless use it primarily as a kind of "blueprint" to a particular water supply system.

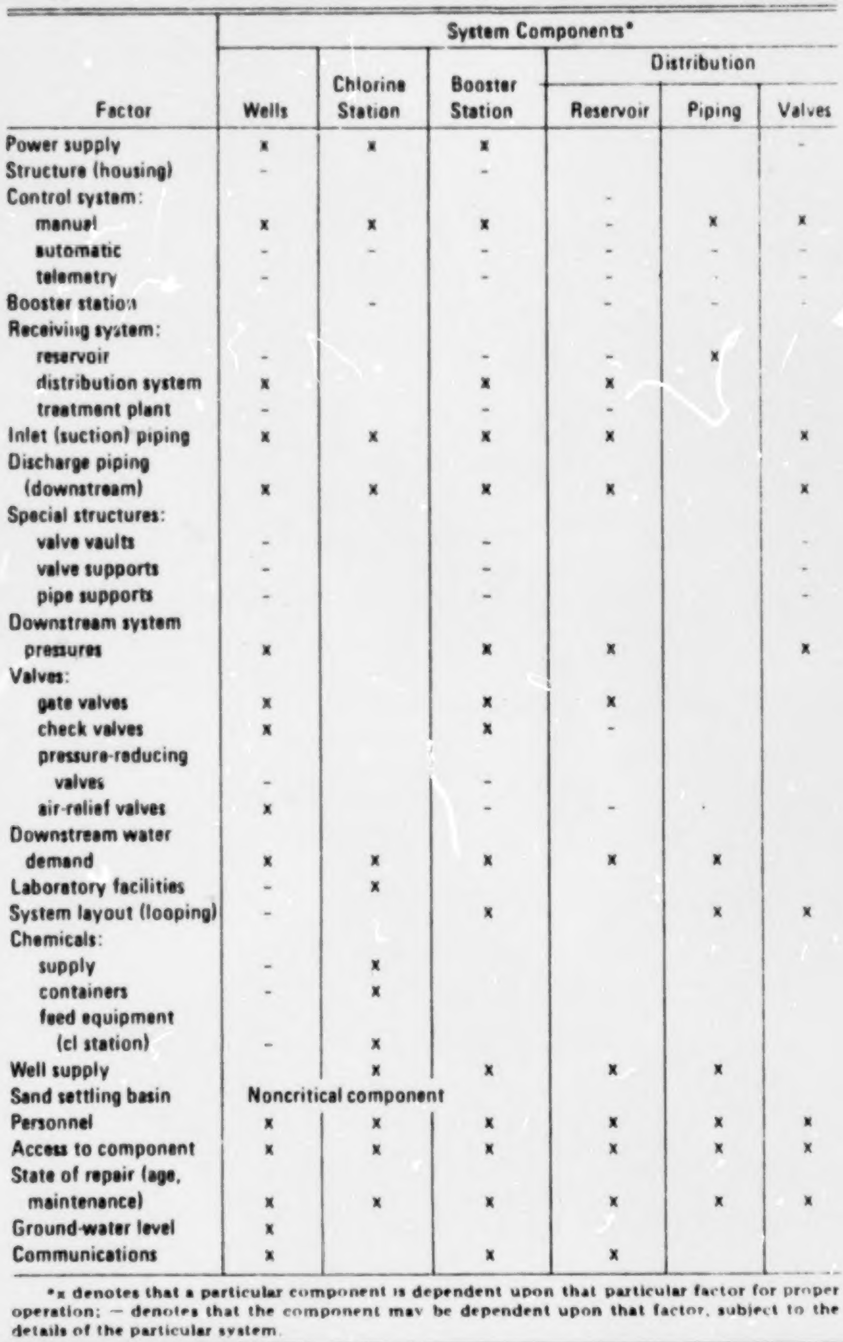
Similarly, administrative records may include "departmental safety-inspection reports" prepared by foremen and workmen or other members of an in-house safety committee. Types of information that may be included in such reports may provide the evaluator with an immediate overview of important structural components of a particular water supply system, as well as with specific issues that affect not only the safety of plant personnel, but also the performance of the total water supply system (Table 18.2)

Each state will require certain reports on a regular basis. These may include financial information, water quality information, etc. The evaluator should make sure that they are being filed and that the information is consistent with the operation.

Specific Issues

As discussed above, the evaluator may utilize very specialized records for general purposes. He may also utilize records containing relatively general information for very specific purposes. For example, Table 18.3 depicts a "utility accounting report" which identifies actual and budgeted expenditures for quite large departments and/or divisions of a utility. Such a report could be utilized by the evaluator to identify large, unplanned-for costs in particular divisions, and therefore potential operational problems that may affect the utility's performance. By way of example, greatly increased expenditures for pumping may indicate the need for pump maintenance. Or a large decrease in costs for purification may cause the evaluator to inquire into operational-testing, and how such testing either confirms or fails to confirm the need for reduced treatment.

The evaluator may be able to generate some very useful information by putting together data from several different record sources. The evaluator can develop a table such as that shown in



Factor	System Components*					
	Wells	Chlorine Station	Booster Station	Distribution		
				Reservoir	Piping	Valves
Power supply	x	x	x			-
Structure (housing)	-		-			
Control system:				-		
manual	x	x	x	-	x	x
automatic	-	-	-	-	-	-
telemetry	-		-	-	-	-
Booster station		-		-	-	-
Receiving system:						
reservoir	-		-	-	x	
distribution system	x		x	x		
treatment plant	-		-	-		
Inlet (suction) piping	x	x	x	x		x
Discharge piping (downstream)	x	x	x	x		x
Special structures:						
valve vaults	-		-			-
valve supports	-		-			-
pipe supports	-		-			-
Downstream system pressures	x		x	x		x
Valves:						
gate valves	x		x	x		
check valves	x		x	-		
pressure-reducing valves	-		-			
air-relief valves	x		-	-		
Downstream water demand	x	x	x	x	x	
Laboratory facilities	-	x				
System layout (looping)	-		x		x	x
Chemicals:						
supply	-	x				
containers	-	x				
feed equipment (cl station)	-	x				
Well supply		x	x	x	x	
Sand settling basin	Noncritical component					
Personnel	x	x	x	x	x	x
Access to component	x	x	x	x	x	x
State of repair (age, maintenance)	x	x	x	x	x	x
Ground-water level	x					
Communications	x		x	x		

*x denotes that a particular component is dependent upon that particular factor for proper operation; – denotes that the component may be dependent upon that factor, subject to the details of the particular system.

Table 18.1 An Example of Types of Information Available in a Vulnerability Study of a Groundwater Supply (Adapted from: American Waterworks Association. 1973. Emergency Planning for Water Utility Management. M19. AWWA, Denver, Colorado.)

Outline of Departmental Safety Inspection Report

Buildings

What is the condition of the floors?
Are hoistways and floor openings guarded?
Are elevated runways and platforms provided with railings and toe-boards?
Are stair treads in good condition?
Are stairways equipped with hand rails?
Is light sufficient?

Fire Hazards

Are there sufficient exits on premises?
Do they open outwards?

Pressure Apparatus, Boilers, Engines, Air Compressors

Is all pressure apparatus equipped with all necessary safety and reducing valves where necessary?
Are fly-wheels, governors and other moving parts properly safeguarded?

Electrical Equipment

Are motors, dynamos, transformers, and all other electrical equipment properly guarded, grounded and insulated?

Grinding Wheels

Are all wheels provided with substantial adjustable relating hoods and safety flanges?
Are *individual* goggles provided and used?

Mechanical Equipment

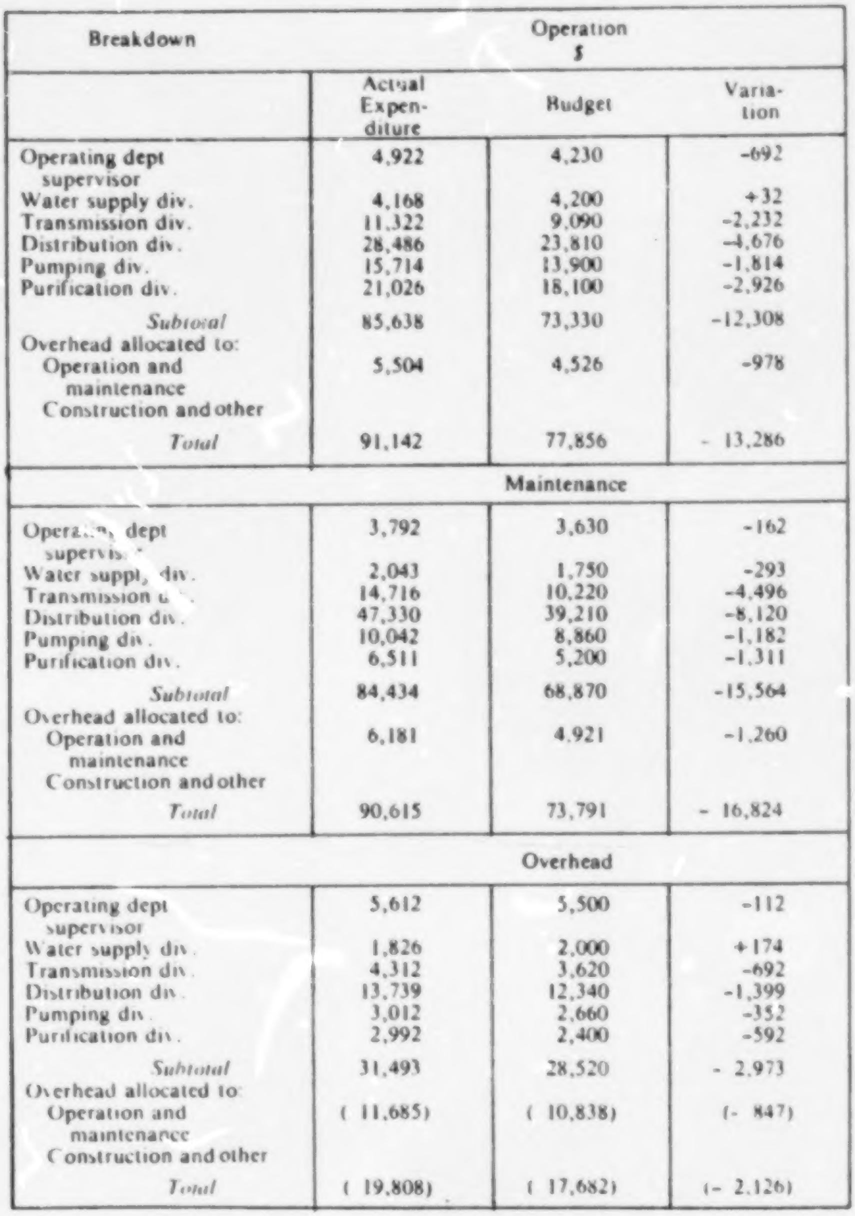
What is the condition of the line shafting?
Is all transmission shafting located within 6 ft of floor or the platform properly guarded?
How many protruding set screws?
How many exposed gears?
Are friction clutches guarded?
How many shaft couplings with exposed nuts, boltheads or keys?
How many unguarded pulleys, vertical, inclined or horizontal belts including rope, chain or sprocket drives?
Is point of operation guarded on all hand-fed machines?
If not how many unguarded?

General Order, Light and Sanitation

Is material properly piled?
Are aisles and passageways kept clear of obstruction?
Is sufficient light provided throughout premises?
Is ample ventilation provided?
Are rooms overcrowded?
Are sanitary facilities provided?
What means are provided for first aid to the injured?
Is first aid equipment complete?

Mobile Equipment (Trucks, Cranes, Diggers)

Table 18.2 An Example of Types of Information Available in a Safety Report (Adapted from: American Waterworks Association. 1959. Water Utility Management. M5. AWWA, Denver, Colorado.)



Breakdown	Operation $		
	Actual Expenditure	Budget	Variation
Operating dept supervisor	4,922	4,230	-692
Water supply div.	4,168	4,200	+32
Transmission div.	11,322	9,090	-2,232
Distribution div.	28,486	23,810	-4,676
Pumping div.	15,714	13,900	-1,814
Purification div.	21,026	18,100	-2,926
Subtotal	85,638	73,330	-12,308
Overhead allocated to:			
Operation and maintenance	5,504	4,526	-978
Construction and other			
Total	91,142	77,856	- 13,286
Maintenance			
Operating dept supervisor	3,792	3,630	-162
Water supply div.	2,043	1,750	-293
Transmission div.	14,716	10,220	-4,496
Distribution div.	47,330	39,210	-8,120
Pumping div.	10,042	8,860	-1,182
Purification div.	6,511	5,200	-1,311
Subtotal	84,434	68,870	-15,564
Overhead allocated to:			
Operation and maintenance	6,181	4,921	-1,260
Construction and other			
Total	90,615	73,791	- 16,824
Overhead			
Operating dept supervisor	5,612	5,500	-112
Water supply div.	1,826	2,000	+174
Transmission div.	4,312	3,620	-692
Distribution div.	13,739	12,340	-1,399
Pumping div.	3,012	2,660	-352
Purification div.	2,992	2,400	-592
Subtotal	31,493	28,520	- 2,973
Overhead allocated to:			
Operation and maintenance	(11,685)	(10,838)	(- 847)
Construction and other			
Total	(19,808)	(17,682)	(- 2,126)

Table 18.3 An Example of a Utility Accounting Report (Adapted from: American Waterworks Association. 1971. Basic Water Treatment Operator's Manual. M18. AWWA, Denver, Colorado.)

Table 18.4. He can collect what figures are available on water drawn for treatment, the amount of water treated, the amount sent to storage or distribution and the amount accounted for by various end uses. This can be done for a particular month, a whole year or an appropriate average. It is also useful to get the same information on an annual peak day basis if it is available. Likewise from other records, the evaluator may get the amount of treatment chemical used for the comparable period.

With this information, he is able to take a broad look at several key issues. For example, the pumping capacity at each stage of the system may be reviewed for adequacy against normal and peak demand. The knowledge of the amount of water billed or accounted for versus the amount sent to the distribution system may indicate leakage problems and/or billing problems. By checking the total amount of chemical used against the total water volume, the evaluation can check to see if the system is carrying close to its desired concentration or useage. If this information is available over several years, trends can be seen. This may alert the water supply system to future problems. This overview approach can be very useful to the water system operator. He may be too much concerned with daily problems to perceive some of these issues.

Follow-Up

Sometimes the information contained in a specific record is sufficient in and by itself to help the evaluator identify a problem and make a recommendation. For example, laboratory records may indicate that required operational-testing is not being performed, or is being performed inadequately, or that finished water quality is sub-standard. Often, however, it is necessary for the evaluator to follow-up information obtained from one set of records by an examination of other and different sets of records. For example, unexplained pumping costs should be evaluated in light of maintenance reports, as well as records of pump installation, type and operation specifications. The inexperienced evaluator should be especially sensitive to the fact that a single bit of information can be very misleading. The experienced evaluator does not act rashly on the basis of limited information obtained from a single record, but uses that information to obtain and elicit other pertinent information which will allow him to make comprehensive recommendations.

	Millions Gallons			
	Peak Day	Total For Month	Total For Year	Daily Average
Water Drawn for Treatment				
Water Pumped to Storage and Distribution				
Water Invoiced				
Other Known Water Useage				
	Lbs or Gallons			
Chemicals Used (1) (2) (3) (4)				
Estimated Concentration				
Desired Concentration				

TABLE 18.4 Overview of Water Supply System Operation.

Summary

The evaluator typically utilizes records to achieve both general and specific objectives (Figure 18.1), including the need to gain a comprehensive overview of the water supply system and to identify and evaluate specific issues affecting the adequacy of the supply system. In order to acheive these objectives, the evaluator should be able to identify specific types of records, and the specific information and data within those records that will be most useful to him. On the basis of this information, his previous experience, and his knowledge of standard and recommended practices, the evaluator must then define and evaluate specific evaluation issues which are most pertinent to the successful and adequate performance of the particular water supply system he is dealing with. In order to carry out the evaluation of such issues and make specific recommendations, he may find it necessary to identify and utilize other and different records, and, also, to elicit pertinent information from operators and other personnel. The evaluator therefore acts so as to coordinate appropriate records and to interpret their significance with respect to the adequacy of the system's design and performance. This task is a central task in the performance of a comprehensive sanitary survey.

Criteria for Evaluating Records

Table 18.5 provides a summary of the criteria that an evaluator can use to evaluate the record keeping function. He must first determine if the records are appropriate to the water supply system. Do they cover the legally required areas and the operating requirements. Secondly, the evaluator must be concerned with the useage of these records. Are they being actively used to run the system? This information is only available from the supervisory and plant operators. A third area of concern is that the records themselves are kept in good order.

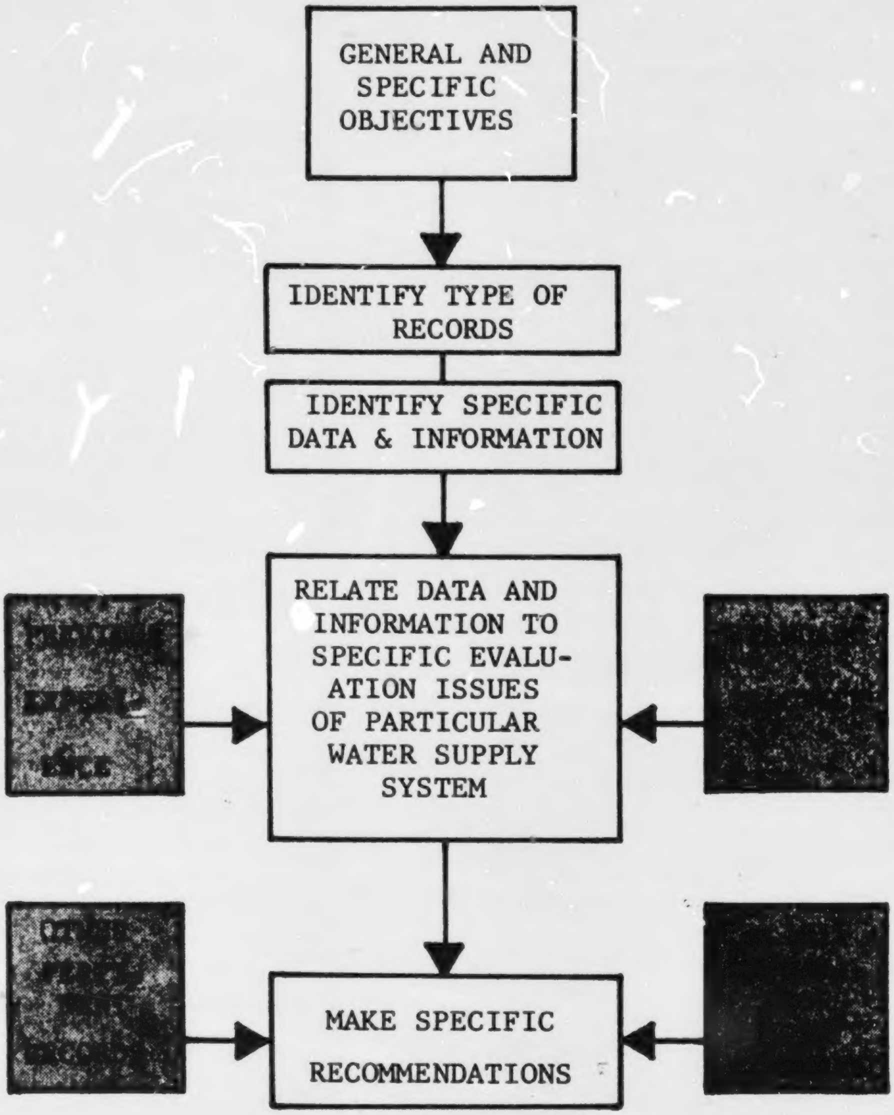

GENERAL AND SPECIFIC OBJECTIVES
IDENTIFY TYPE OF RECORDS
IDENTIFY SPECIFIC DATA & INFORMATION
RELATE DATA AND INFORMATION TO SPECIFIC EVALUATION ISSUES OF PARTICULAR WATER SUPPLY SYSTEM
MAKE SPECIFIC RECOMMENDATIONS

Figure 18.1 Summary of Evaluator's Use of Records.

TABLE 18.5 Guidelines for Evaluating Public Water Supplies

Function: Control

Subfunction: Records

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Records 1. State required operating reports	Describe flow (pumpage) & chemical use		Adequacy	1. Stored safely 2. Legible & understandable 3. Continual update 4. Completeness 5. Utilization 6. Available to users 7. Timely reporting to state as required	
2. Water Quality reports	Describe raw and finished quality.				
3. Budget, income & expense reports	Describe stability of system.				
4. System and organization desc. records	Describe how system is operated.				
5. Complaints	Describe consumer satisfaction.				
6. Special purpose	Describe emergency plan, future growth plans,				

TABLE 18.5 (Cont.) Guidelines for Evaluating Public Water Supplies

Function: Control

Subfunction: Records

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
6. (Cont.)	safety records, maintenance				
List Records Kept By Utility	Describe how records kept are used				

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 19

MAINTENANCE

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

MAINTENANCE

PURPOSE:
The maintenance of equipment is critical to the operation of the water supply. This module suggests some of the issues that an evaluator may review to determine how well the maintenance is executed.

OBJECTIVES:
(1) The student will be able to identify specific elements that are important to a good maintenance program.
(2) The student will be able to list means by which he can evaluate the maintenance program.

CONTENT:
Introduction
Overview of Types of Maintenance Programs
Evaluation Criteria for Maintenance Programs
Criteria for Evaluating Maintenance of Treatment Processes
Criteria for Evaluating Maintenance of the Distribution System

OTHER RELEVANT MODULES:

All Modules.

Introduction

The maintenance policies of the management of a water supply system are often indicative of the overall quality level of the operation. The operation of the system is heavily dependent on maintenance. Yet maintenance is often deferred. Lack of manpower or lack of budget are cited as reasons for poor maintenance. Maintenance is an area in which management may cut back expenses today, but it is often at a severe future cost. Unless a critical point of the system is out of order, employees are often assigned to other tasks that are considered "more important".

Most activities within a water supply system can be measured by some means which shows accomplishment of the objectives. Maintenance or the lack of it is most apparent by the failures in the system. For this reason management must give special emphasis to the execution of the maintenance policies and programs. This emphasis must begin with careful designation of who is responsible for the maintenance and then make sure that they have the authority to perform the tasks (Module 16). The organizational set-up and the job descriptions must be carefully linked to the facilities and equipment. Once the structural part of the program is set-up, it still takes strong management action to ensure success. Management must make its maintenance objectives and policies known to all members of the organization. As in other management responsibilities, they must follow-up to see that the objectives are being reached.

Overview of Types of Maintenance Programs

Maintenance activities are normally divided into two categories: those associated with breakdowns and those associated with preventive maintenance. Although it would be ideal to eliminate all breakdown maintenance activities, it is probably not an achievable objective. The American Water Works Association has suggested that a reasonable target is to spend no more than 20 percent of the man-hours of equipment maintenance on breakdown maintenance.[1]

The reasonableness of this target will obviously depend on the equipment and type of system. Perhaps, the most important aspect is that the management recognize that there should be a target and that progress is measured.

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[1] American Water Works Association, Inc. 1959. Water Utility Management. Manual M5. AWWA, Denver, Colorado.

The breakdown maintenance program may require different skills. Rapid response, ingenuity through knowledge of the interactions of the entire system are all important attributes. Planning in this area consists primarily of playing the "What If" game just as in emergency planning (Module 21). Availability of extra part-time trained personnel is an ideal asset for dealing with repairs. In a short visit, an evaluator may not be able to do more than check on the planning, and the training of personnel for this aspect of the maintenance program.

Preventive maintenance should be viewed as an alternative plan to having large quantities of stand-by equipment. Management must decide to what degree they will reduce the risk of failure. This decision may depend upon the perceived consequences of equipment failure. The range of alternatives available to the manager include the following possibilities :

(1) Stand-by equipment

(2) Various levels of preventive maintenance

(3) Breakdown maintenance only.

Because of the risks of a breakdown program and the high cost of stand-by equipment, preventive maintenance is often chosen as the best alternative. Before an evaluator can fairly measure this aspect of a water supply system, he needs to know management's policy.

Evaluation Criteria for Maintenance Programs

In reviewing the maintenance program of a water supply the evaluator may look at three different aspects:

(1) General housekeeping

(2) Administration

(3) Maintenance of equipment and processes.

The latter is discussed in the sections below.

The evaluator may form general impressions by noting the housekeeping as he tours the facilities. This applies to the office and grounds as well as the plant and laboratory. The general state of repair, the cleanliness, and orderliness are potential criteria. Because these judgements tend to be subjective, the evaluator must be specific in his notations and oral and written citations. By referring to reasons (public image, personnel safety, fire hazard, etc.) for improvement in this aspect of maintenance, the evaluator may achieve better results. See Table 19.1 for further evaluation criteria.

The administration of a maintenance system may be evaluated in terms of the type of system and its actual operation. The program does require extensive record keeping. Each piece of equipment must have records associated with it. A full description of the equipment, its operation, and the maintenance requirements provides the necessary background material. In addition, a log of both preventive and breakdown maintenance activities performed should be kept. The preventive maintenance schedule for each piece of equipment must be drawn together into a schedule to be used to plan and control the maintenance for all of the system. Besides procedures the system will need a supply of spare parts for some items. What to carry in inventory and how many will be important decisions. This inventory may depend on the existence of a water supply system-owned maintenance shop. If the system does not have a shop, the evaluator should see if the system has sources for these services.

The existence of the system is an important part of the program. Its actual implementation is also important. The evaluator should search for evidence that the personnel know who is to do what, that the maintenance is performed and that the logs are kept current. A few questions of the personnel and random reviews of the logs during the tour will help determine the effectiveness of the implementation.

Criteria for Evaluating Maintenance of Treatment Processes

It is important for the evaluator not to accept in-plant housekeeping as fully adequate treatment plant maintenance. Housekeeping is usually the more visible aspect of maintenance. Housekeeping is manifest in clean premises (in many plants "hospital" or "white glove" spotlessness) and employee personal cleanliness rivaling or exceeding that required in the food and beverage industries. The evaluator must also look beneath the surface and consider plant operation under the worst of adverse conditions.

TABLE 19.1 Guidelines for Evaluating Public Water Supplies

Function: Control

Subfunction: Maintenance - Housekeeping

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
All Facilities	Subjective observation of the appearance of facilities		Adequacy and Safety	1. Pleasing appearance 2. Clean 3. Recently painted 4. Grounds well kept 5. Supplies on hand kept neatly and properly stored 6. Operator's appearance	

A plant experiencing extreme weather conditions, operating with stand-by power, having had to cope with several equipment failures all aggravated by either short supply or unusually high demand and delivering a finished water quality equal or nearly equal to normal operations undoubtedly has an outstanding maintenance program. Good maintenance assures continued operation.

The evaluator should carefully analyse the "flow through" aspect of the total plant operation and the "critical path". If the "critical path" depends on a certain piece of equipment, such as an electrically driven pump, replacement components should be readily available. It may not be necessary, due to cost, to have these components on the shelf if a reliable retailer is located near by. It is usually a good idea to have some arrangement with the retailer so that he knows that the water supply system is depending upon him for back up. See Table 19.2 .

The spare parts inventory is not as easily resolved. The size and complexity of the treatment plant and the skill and experience of maintenance personnel will determine the desired level. Almost all facilities should have basic electrical spare parts such as fuses, switches, connectors and insulated wire. Even if an on-call electrician is available, in-plant personnel should have enough electrical back up to keep the plant operating for a short period of time. Similarly, a plant should stock basic plumbing and piping parts such as nipples, unions, couplings, elbows and other fittings, valves, and a few lengths of appropriately sized pipe. This material should be accompanied by adequate equipment, however minimal, for installation like pipe threading dies and taps. See Table 19.3 .

The evaluator should not overlook the importance of electrical wiring and proper piping and pipe support. Temporary repairs in either of these services should be minimal. Keep in mind that temporary repairs should be in fact, temporary, and permanent repairs completed as soon as possible. Leaks anywhere in the treatment plant, especially in chlorine and other chemical handling equipment, cannot be tolerated and should be properly repaired immediately.

Plant personnel must be mindful on a day-to-day basis of the importance of preventive maintenance especially lubrication. Any irregularities of equipment operation including vibration and/or noise should be dealt with on a top priority basis. Finally,

TABLE 19.2 Guidelines for Evaluating Public Water Supplies

Function: Control

Subfunction: Maintenance (Intake through Treatment)

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Preventive Maintenance Program	To avoid breakdowns interrupting the continuous delivery of safe, adequate supplies of potable water To assure rapid repair of out-of-service system components, minimizing interruptions to the delivery of safe, adequate supplies of potable water.		Adequacy	1. Intake structure a) check of screens (frequency) b) corrosion control c) lubrication of moving parts d) replacement criteria 2. Pumps -See O & M manuals & mfr. specs. 3. Flocculation & sedimentation a) lubrication of moving parts b) Insp. Freq.	Overall 1. O & M Manuals provided for plant as a whole

TABLE 19.2 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Control

Subfunction: Maintenance (Intake through Treatment)

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Adequacy (Cont.)	4. Filters a) media inspection b) valve insp. & operation c) gage calibration d) backwash equip.insp. 5. Chemical feed and storage a) cleanliness b) insp. & lubrication of ventilation equip. c) Insp. & lubr. of moving parts.	

TABLE 19.3 Guidelines for Evaluating Public Water Supplies

Function: Control

Subfunction: Maintenance (Intake through Treatment)

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Breakdown Maintenance Program	To assure rapid repair of out-of-service system components, minimizing interruptions to the delivery of safe adequate supplies of potable water		Adequacy	1. Reaction plan developed for breakdown of critical components 2. Inventory of critical parts necessary to quick repair 3. Knowledge of sources of repair parts-manufacturers & other utilities nearby 4. Personnel trained in critical repair work	

TABLE 19.3 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Control

Subfunction: Maintenance (Intake through Treatment)

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Adequacy (Cont.)	5. Availability of tools necessary to repair.	

it should be kept in mind that stand-by equipment must be put "on line" regularly to assure adequate performance during time of need.

Criteria for Evaluating Maintenance of the Distribution System

Maintenance of the distribution system should be directed toward the same goal as maintenance of treatment processes, i.e., satisfactory operation under the worst of conditions. The distribution system serves a double public utility service by not only providing potable water to consumers but serving as the very basis of the municipality's fire fighting capacity.

Distribution maintenance involves much routine record keeping and operations such as:

(1) Locating all service connections and repairs and making a record.

(2) Operating all system valves regularly.

(3) Operating all system hydrants regularly.

(4) Inspecting tanks and reservoirs for structural, sanitary and operational safety.

(5) Keeping up-to-date and accurate records of all new construction as part of a general overall system upgrading program. Ideally, the age, material, and condition of every foot of pipe should be documented.

Distribution personnel most likely will be used to being outside in all kinds of weather at all hours of the day and night. Usually their greatest asset is first hand knowledge of the physical system and its operation. The evaluator must approach maintenance issues with these factors in mind realizing that attitudinal aspects can be of vital importance. It should be obvious that good maintenance of the distribution system is not usually at all apparent or visible.

Table 19.4 summarizes the evaluation criteria for adequacy and protection.

TABLE 19.4 Guidelines for Evaluating Public Water Supplies

Function: Control

Subfunction: Maintenance - Distribution & Storage

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
See Distribution Module	See Distribution Module		Adequacy	1. Valves operated periodically 2. Main flush program 3. Hydrants checked & serviced 4. Meter program a) calibration b) replacement 5. Repair matl. available 6. Corrosion control a) cathodic servicing b) painting 7. Storage facilities inspection a) meters &	

TABLE 19.4 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Control

Subfunction: Maintenance - Distribution & Storage

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
			Adequacy (Cont.)	gauges. b) valves	
			Protection	1. Leak survey program 2. Backflow prevention servicing 3. Storage facilities cleaning a) screens b) openings c) overflows	

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 20

SAFETY

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

SAFETY

PURPOSE:

The purpose of this module is to develop and discuss issues to be considered in the evaluation of safety in a water supply system.

OBJECTIVES:

(1) The student will be able to list specific design and operational features of a supply system, and to relate these features to safety hazards.

(2) The student will be able to identify and discuss some general guidelines for evaluating safety in a water supply system.

CONTENT:

Introduction
System Design
System Operation
Guidelines

OTHER RELEVANT MODULES:

Module No. 2. Evaluation
Module No. 11. Chemical Feed and Storage
Module No. 18. Records
Module No. 21. Emergency Plans

Introduction

Any safety program in any water supply system has two related objectives: (1) to ensure the safety of individual personnel and of the public having access to water supply facilities and grounds, and (2) to ensure the proper functioning of the water supply system.

Injuries to personnel are important not only because of the losses suffered by the individual, but also because of the potential for such losses to affect the continual production and delivery of adequate volumes of safe water.

A comprehensive evaluation of safety should include considerations of all structural and functional components (Module No. 2) of a water supply system. Such an evaluation should be done by the water utility management. From this evaluation should come safety protocols, programs and procedures identified and documented in the records. These management policies are then related to safety measures actually practiced by the system's staff.

System Design

Safety begins with the design of a water supply system, including such design features as:

- location and layout of surface structures, including open channels, ditches, cisterns, storage reservoirs, tanks, cables, pipes, etc.
- structural stability of a variety of surface and sub-surface structures, including foundations, power-poles, roofs and other covers, backfill, riprap, protective fences and guide rails, etc.
- location and adequacy of major protective and control devices and features, including vents and blowers, shut-off valves, eye and body showers, etc.
- location and adequacy of portable emergency equipment and materials, including fire fighting equipment, medical and first aid equipment and supplies, gas masks, protective garments, special tools, etc.

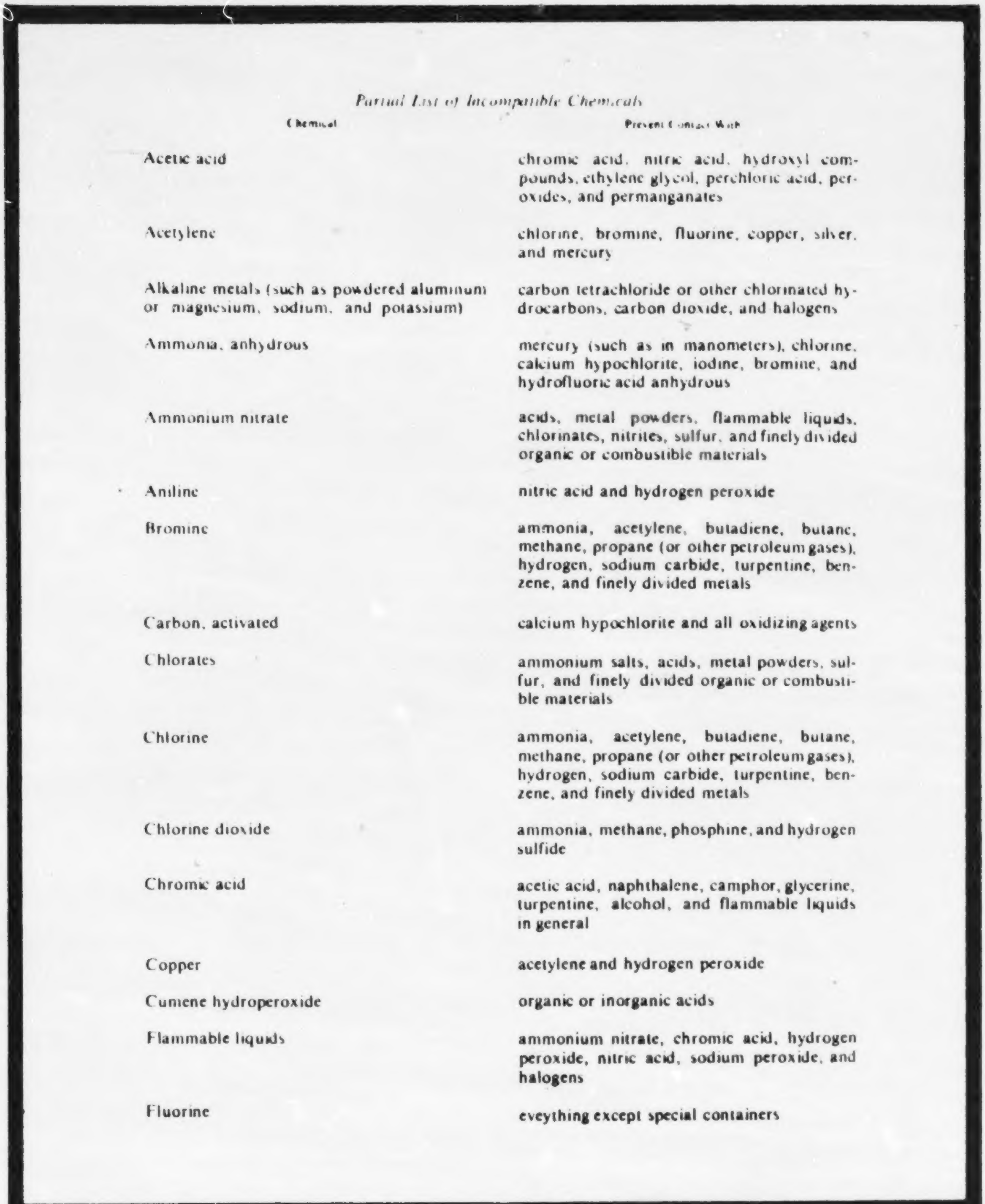
System Operation

The most carefully designed water supply system is only as safe as the manner in which operations are actually conducted.

For example, a storage area (Module No. 11) may be well designed from the point of view of environmental control, isolation from routine activities and interferences, and available emergency equipment. However, such design is useless for preventing safety hazards if personnel do not utilize the storage area properly, and continue to store incompatible chemicals in close proximity within the storage area. As depicted in Table 20.1, lists are available which clearly indicate which chemicals should be carefully separated from other chemicals. As an example, the evaluator will want to note whether the actual operation of storage areas conforms to safe practices, whether there is administrative concern and action for ensuring personnel understanding and practice of safety rules, and whether appropriate guidelines and information is readily available to personnel.

Some key issues involved in the evaluation of operational safety include:

- standard protective equipment and protocols for handling, storing, mixing, and utilizing chemicals and other needed supplies
- preventive and corrective maintenance by qualified personnel and according to manufacturer's specifications for equipment and devices
- periodic safety inspections and reports, and follow-up actions taken in response to identified hazards
- safety training program for new personnel, and periodic updating and review training for experienced personnel
- safety drills (announced and unannounced) for in-plant emergencies, including drills in first - aid measures
- secure and/or backup communication links with fire departments, hospitals, and other special services.



Partial List of Incompatible Chemicals

Chemical	Prevent Contact With
Acetic acid	chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, and permanganates
Acetylene	chlorine, bromine, fluorine, copper, silver, and mercury
Alkaline metals (such as powdered aluminum or magnesium, sodium, and potassium)	carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, and halogens
Ammonia, anhydrous	mercury (such as in manometers), chlorine, calcium hypochlorite, iodine, bromine, and hydrofluoric acid anhydrous
Ammonium nitrate	acids, metal powders, flammable liquids, chlorinates, nitrites, sulfur, and finely divided organic or combustible materials
Aniline	nitric acid and hydrogen peroxide
Bromine	ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, and finely divided metals
Carbon, activated	calcium hypochlorite and all oxidizing agents
Chlorates	ammonium salts, acids, metal powders, sulfur, and finely divided organic or combustible materials
Chlorine	ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, and finely divided metals
Chlorine dioxide	ammonia, methane, phosphine, and hydrogen sulfide
Chromic acid	acetic acid, naphthalene, camphor, glycerine, turpentine, alcohol, and flammable liquids in general
Copper	acetylene and hydrogen peroxide
Cumene hydroperoxide	organic or inorganic acids
Flammable liquids	ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, and halogens
Fluorine	eveything except special containers

Table 20.1 Incompatible Chemicals (Adapted from: American Water Works Association. 1971. Safety Practice for Water Utilities. Second Edition. M3. AWWA, New York, New York).

For most small supplies these issues become very elementary and are primarily related to the first two issues.

Guidelines

Three general guidelines should be employed by the evaluator in the progress of his evaluation.

First, the evaluator should consider the attitudes of plant personnel and administrators with respect to safety. A casual approach to safety increases the potential for injury both to personnel and to the public.

Second, the evaluator should identify the status of the utilities safety program, if any. Has a conscious effort been made to consider safety in the design and operation of all components of the system? Are safety protocols, programs and practices established as policy in writing?

Third, the evaluator, through questioning of staff and observation determine whether good safety practices have been implemented particularly in high risk areas such as chemical handling and storage, excavation, and confined area work.

CONDUCTING
SANITARY SURVEYS
OF
WATER SUPPLY SYSTEMS

MODULE NO: 21

EMERGENCY PLANS

TITLE OF COURSE:

CONDUCTING SANITARY SURVEYS OF WATER SUPPLY SYSTEMS

TITLE OF MODULE:

EMERGENCY PLANS

PURPOSE:

Because water supplies are vital to a community, the management should be prepared to deal effectively with common emergencies. The contingency plans should be part of the evaluation.

OBJECTIVES:

(1) The student will be able to identify potential emergencies and what parts of the system they may affect.
(2) The student will be able to identify criteria by which to evaluate the contingency plans of a water supply system.

CONTENT:

Introduction
Types of Emergencies
Potential Effects on the System
Criteria for Evaluation

OTHER RELEVANT MODULES:

All Modules

Introduction

The pressure of daily problems on the water supply system manager tends to place the development of emergency plans on a low priority. If these plans are developed at all, they are probably very cursory. The continuous supply of drinkable water to a community is so vital that the community should demand that adequate contingency plans exist. The Safe Drinking Water Act, in fact, requires that states develop emergency contingency plans, a requirement which most states will pass along to local systems.

A well developed contingency plan requires the development of assumptions about emergencies, an estimate of remaining capabilities of the system, an estimate of the continuing community demand and some realistic assessments of the capability to meet those requirements. After this background has been developed, the plan emerges as a set of priorities, programs for using the resources remaining and the assignment of specific tasks to personnel. While an evaluator may not be able to review the plan development process in detail, an overview of certain aspects will be useful in the evaluation.

Types of Emergencies

Emergencies may be classified in terms of their pervasiveness and the probability of cocurrence. The pervasive natural and man-made disasters include such things as earthquakes, volcanic eruption, war, sabotage, civil disorder, etc. These events have a very low probability of occurrence and may be so pervasive that the contingency plans are beyond the scope of one water supply.

The prime concern of the evaluator is with the more common less pervasive events which may affect a water supply system. These may include power outages, breaks in the water main, flooding, fires, major storms, chemical contamination through cross connections or spills, etc.

Potential Effects on the System

Emergency plans should be developed for any event which may "reasonably" occur. Table 21.1 shows a partial listing of such events. Each event should be reviewed for its potential effects on the water supply's objective; i.e., the delivery of adequate quantities of safe, palatable drinking water. These effects must then be examined to determine how each can be alleviated to accomplish the water supply's objective. This analysis will identify

What If	COLLECTION	TREATMENT	DISTRIBUTION
Fire in Plant		o	o
Fire in Community			o
Power Failure	o	o	o
Breaks in Major Pipeline	o		o
Treatment System Failure		o	o
Outbreak of Water-borne Disease	o	o	o
Toxic Chemical Contamination - Cross Connection		o	o
Extreme Natural Events: Flooding, Drought, Extreme, Freezing, Tornado	o	o	o
Chemical Spills Affecting Source	o		
Vandalism or Explosion	o		o

Table 21.1 Potential Effects of Types of Emergencies.

the critical components of the system in each event. It may show an immediate need to provide alternative operational mechanisms or insulate the critical component from the potential damages. This analysis helps the development of cost and time effective solutions by concentrating efforts on components most likely to be affected by different types of emergencies. Table 21.2 shows what emergency plans are applicable to the types of emergencies shown in Table 21.1 . The evaluator can use this table to check the completeness of a water supply's emergency plan.

Criteria for Evaluation

The evaluation of emergency plans must consider three basic aspects:

(1) Do they exist on paper?

(2) Are they adequate?

(3) Are the employees, who are responsible for implementation, familiar with the plans.

The existence and familiarity of the employees with the plan are easily ascertainable by the evaluator.

The adequacy of emergency plans will be more difficult to determine. The plan should clearly state the objectives and what measures will be taken to accomplish the objective. Who does what, and when, should also be specified. One aspect often overlooked is the need to communicate with the municipal authorities and the public. The plan should include a means of informing the public of the problem and providing information that will assist the public taking action that will assure a safe supply of drinking water. Lastly, the measures that are being proposed should be evaluated as to their effectiveness in protecting public health and providing an adequate supply. Table 21.3 summarizes the criteria an evaluator can use in reviewing emergency plans.

	EMERGENCY									
	Fire in Plant	Fire in Community	Power Failure	Breaks in Major Pipeline	Treatment System Failure	Outbreak of Waterborne Disease	X-Connection Toxic Chemical	Natural Events	Chemical Spills at Source	Vandalism
Lab Testing for Detection, Identification and Monitoring				X	X	X	X	X	X	X
Use Alternate Sources of Water		X	X		X	X	X	X	X	X
Temporary Consumption of Finished Water	X	X	X		X			X	X	X
Notification of Public to Reduce Use	X	X	X					X		X
Notification of Public to Boil Water Before Use					X	X	X	X	X	
Isolate Section of Distribution System				X		X	X	X		X
Emergency Standby Power	X		X					X		
Standby Pumps	X	X						X		
Standby Chemical Feed Equipment	X				X			X		
Capacity for Dilution					X			X	X	

Table 21.2 Emergency Plans Relevant to Common Emergencies.

	EMERGENCY									
	Fire in Plant	Fire in Community	Power Failure	Breaks in Major Pipeline	Treatment System Failure	Outbreak of Waterborne Disease	X-Connection Toxic Chemical	Natural Events	Chemical Spills at Source	Vandalism
Ability to Detain in Reservoir						X		X	X	X
Ability to Change Intake Structure						X		X	X	
Stockpiling of Chemicals						X		X	X	
Coordination with Police and Fire Departments		X		X				X		X

Table 21.2 (Cont.) Emergency Plans Relevant to Common Emergencies.

SECTION F

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SECTION G

NOTEPAPER

TABLE 21.3 Guidelines for Evaluating Public Water Supplies

Function: Control

Subfunction: Emergency Planning

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
Emergency Plans - Describe 1. Major Community Fire 2. Power Failure 3. Major Main Break 4. Treatment System Failure 5. Waterborne Disease Outbreak 6. Major Cross-Connection Contamin. 7. Spill Affecting Source	To assure that a continuous supply of adequate, safe, palatable water is available under adverse conditions		Adequacy	1. Emergencies considered 2. Order of reaction steps identified 3. Responsible individuals for each step and means of contact identified 4. Public and state notification conditions identified 5. Awareness of plan in responsible individuals	

TABLE 21.3 Guidelines for Evaluating Public Water Supplies
(Cont.)

Function: Control

Subfunction: Emergency Planning

Objective:

1	2	3	4	5	6
System Component	Component Objective	Responsible Person for Component	Evaluation Objective	Evaluation Criteria	Evaluation Conclusion
8. Extreme natural event: flooding, drought, extreme freezing, tornado			Adequacy (Cont.)	6. Past history of emergencies	